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Contents

Book Reviews

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Book Reviews

In This Issue

Two of the three articles in this issue examine economic features of the Nation's conservation policies. The authors examine cost, price, and production effects of the Conservation Reserve Program (CRP).

In their article on price and production effects of the CRP, Hertel and Preckel employ a summary function technique to analyze the effects of an increase in the conservation reserve on commodity prices and CRP rentals. Their method, which accounts for interaction among commodities, reduces the expected effect of the program on commodity prices. They show that bid prices for CRP land are likely to rise as the program expands.

Barbarika and Dicks estimate the costs of reducing soil erosion on highly erodible land. Assuming a CRP signup of 40-45 million acres and the adoption of conservation tillage, they estimate that 46 million acres of cropland will need treatment to reduce erosion to acceptable soil loss levels at an annual cost of $667 million.

The two articles tell us that conservation has a cost and that conservation programs may have ripple effects through commodity and land prices. Neither article intended to estimate the value of conservation or conservation programs. Perhaps we can leave that task to Leopold:

> It is inconceivable to me that an ethical relation to land can exist without love, respect, and admiration for land, and a high regard for its value. By value, I of course mean something far broader than mere economic value.
>
> (*A Sand County Almanac*, p. 223)

Swamy, Conway, and LeBlanc present the second in a series of three articles on stochastic coefficients. Their previous article addressed problems associated with fixed-coefficients; now they examine the advantages and disadvantages of stochastic coefficients. Compared with models with fixed coefficients, the stochastic equations show low robustness without restrictions on parameters, and restrictions reduce the equations to a fixed-coefficients model. Never mind, the real aim of inference is prediction, and stochastic coefficients models are well suited to prediction.

The book reviews in this issue run from econometric theory and methods through applied economics to public policy. Monaco appraises the *Handbook of Econometrics* by Griliches and Intriligator as rough going for someone without a strong background in econometric theory, but it is carefully written and edited. He recommends it as a complement to a good econometrics test.

Another collection of papers, *Proceedings of the Conference on Common Property Resource Management,* fares less well in Milon's review. Although he compliments a number of individual contributions, particularly many of the case studies, Milon believes the volume leaves many unanswered questions about common property.

Public Policy and Agricultural Technology: Adversity Despite Achievement, a collection of essays by Hadwiger and Browne, should have been rejected for its title, but Schaller charitably assesses its contents and concludes that it really has some good chapters on technology and agricultural research policy. However, the book's disconnected whole is probably less than the sum of its parts. Another collection of essays, *World Food Policies: Toward Agricultural Interdependence,* edited this time by Brown and Hadwiger, also has some strong elements, according to Kennedy, but none of the essays provides the global perspective that the title suggests. The editors of these two volumes are political scientists, so agricultural economists might read them for another perspective.

Reichelderfer gives high marks to *Weed Control Economics* but believes its narrow-sounding title will probably deter many who could greatly benefit from the book. Although it performs well on the subject of its title, it could easily be "a blueprint for the systematic evaluation of any farm management practice." Unlike the other books reviewed this time, this one is not a collection of essays, and it shows. It is a compact book written with a singularity of purpose seldom found in collections.

I have the impression that books in agricultural economics research increasingly take the form of collections of essays. Four of the five books reviewed in this issue, for example, were edited collections. If my impression is correct, is it a symptom of increased specialization? Are combined efforts needed to produce a usable publication? Is the material of the profession too complex to be treated by one person? If so, then how should the material of the profession be represented, either episodically in collections or serially in journals? If McLuhan and Postman are correct, that is, that the medium is the message, then our profession should examine the way its product is packaged.

Gene Wunderlich

Commodity-Specific Effects of the Conservation Reserve Program

Thomas W. Hertel and Paul V. Preckel

Abstract. *A summary function describing the relationship between output level, conservation reserve program (CRP) acreage, and production costs for major U.S. field crops indicates that extending the CRP from 40 million to 44 million acres in 1990 could raise the bid price for CRP land by as much as 7 percent. The estimated effect on commodity prices is modest and depends largely on interactions with other farm programs. Previous research has probably overstated the commodity price effects of the CRP because of insuffficient treatment of cross-commodity effects.*

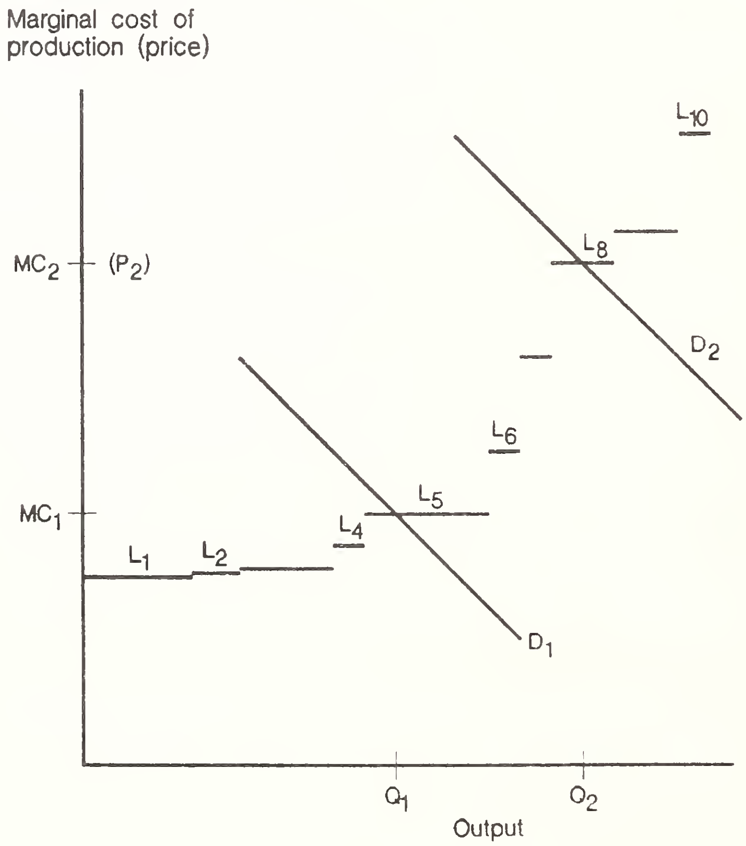
Keywords. *Conservation reserve, summary function, commodity prices.*

The 1985 Food Security Act introduced a conservation reserve designed to withdraw 40-45 million acres of erodible cropland from production by 1990. A conservation program of this magnitude can be expected to dramatically affect agricultural commodity markets and the cost of other farm programs. In addition to reducing erosion, the program will absorb some of the excess capacity of U.S. agriculture, thereby bolstering farm prices and reducing program payments. In a recent ERS report, Webb, Ogg, and Huang have attempted to quantify the magnitude of these effects *(15)*.[1] They find that retiring 32 million acres of highly erodible cropland would significantly affect commodity prices and would probably save the Government over $5 billion a year in deficiency and storage payments. Our purpose here is to refine their estimates of the likely commodity market effects of the Conservation Reserve Program (CRP). We will focus on marginal, rather than total, effects. The major question is: What would be the likely effects of enlarging the CRP in 1990?

Figure 1 illustrates the basic problem. It shows the marginal cost of production solely as a function of land type and output level (prices and intensities of other factors are held constant). Producers are assumed to use the best land first, resulting in a step-function in which constant returns to scale apply for any given land type and marginal costs rise only as less productive land is brought into production. Thus, at the level of demand depicted by D_1, the cost of production on land type L_5 determines marginal cost and thereby commodity price. Ricardian rents accrue to land types L_1-L_4, and other land (L_6-L_{10}) is idled.

It is easy to see that the impact of the CRP on the marginal cost of production will depend on the productivity of land withdrawn (fig. 1). If the erodible land is also the least productive, there may be little effect on prices. For example, at the lower level of demand, any land withdrawn from L_6-L_{10} (as well as marginal amounts from L_5) will have no price effects. By contrast, the maximum backward shift in the supply curve and, hence, the largest price effect can be achieved by the withdrawal of land type L_1. Next, consider the effect of enlarging the CRP when demand is at the higher level, D_2 in figure 1. At this higher price (P_2), land types

Figure 1
Marginal production costs in a linear programming (LP) model with different land types



The authors are assistant professors in the Department of Agricultural Economics, Purdue University. This research was conducted under a cooperative agreement with the Policy Branch of the Resources and Technology Division (RTD), ERS. The authors would like to thank Wen Huang for his assistance in assembling the baseline data set. John Miranowski, Tony Grano, Clay Ogg, Mike Dicks, and others in RTD provided stimulating comments and suggestions on this research.

[1]Italicized numbers in parentheses refer to items in the References at the end of this article.

L_5 to L_7 are no longer marginal. Enrolling more of this land in the CRP now affects the market price. Furthermore, since the Ricardian rents on all land in production will be higher, bid prices for additional CRP land will also rise.

We have highlighted the importance of identifying which land will be targeted by the CRP and what its potential productivity is. Any modeling framework that treats land as a homogeneous input will miss the point of figure 1 entirely. Webb and others *(15)* utilize a land capability classification scheme *(7)* that permits identification of both erosion potential and productivity of different land types. They proceed by solving a version of the Iowa State/Center for Agriculture and Rural Development (CARD) model *(5, 11)* with the erodible land in the available base acreage. The production impact of a CRP-type scheme is then assumed equal to the output produced on the erodible acreage in the base solution. Another approach would involve resolving the linear programming (LP) model with the erodible acreage eliminated from the resource endowments. The increased marginal cost of producing the base output vector would indicate the backward shift in the supply curve in figure 1.

Neither of these approaches, however, provides any information about the shape and local behavior of the marginal cost curves of individual crops. Such qualitative information can be extremely useful in evaluating the sensitivity of the results to different levels of both demand and the CRP. This type of information is particularly important in light of recent proposals to extend the CRP beyond 40 million acres. The summary function developed in this article systematically reveals the marginal cost functions of individual crops that are implicit in the CARD model. Thus, it provides useful supplementary information to policymakers concerned about the commodity-specific effects of the CRP.

Having created a summary function, we then proceed to conduct a simple multimarket equilibrium analysis for corn, wheat, and soybeans. We estimate the commodity price and bid price effects of extending the CRP. The results demonstrate why previous analysis *(15)* has probably overstated the commodity price effects of the CRP.

Model Description and Base Case

Our study draws on the same general model structure and data base as the report of Webb and others *(15)*. We employed a version of the CARD linear program that minimizes costs of crop production subject to exogenous national demands and a variety of resource constraints.[2] We utilized the LP model at the 31-market-region level with the same six land groups developed for the earlier study. Acreage was further grouped into three irrigation classes: dry land, surface-irrigated, and ground-irrigated. This grouping gives rise to 558 constraints on land availability by region, land group, and irrigation class. Demands for the major crops (barley, corn, cotton, oats, sorghum, soybeans, and wheat) are treated as fixed quantities at the projected (1990) national levels, with lower bounds on commodity acreage in each region. (Constraints on hay and summer fallow are set only at the national level.) Upper bounds on conservation tillage acreage were set at 50 percent for each region. To permit the summary function algorithm to be applied economically, we limited tillage practices to conventional practices with and without conservation tillage and with and without irrigation. The resulting LP had 830 constraints, 6,582 variables, and 60,000 nonzero coefficients.

A summary function is a local approximation to the LP. Hence, the base solution (about which the local approximation is constructed) is important. There are two key components to the 1990 baseline data set: the land base and the levels of national demands.[3] Table 1 details the land base, by six land groups. Columns two through four identify the characteristics of each land group by capability classes, erosion potential, and relative yields. Groups 1 and 3 exhibit the highest yields, while groups 4-6 have the greatest potential for erosion. Group 2 has both low yield and low erosion potential.

The next column in table 1 shows total acreage, by land group, as provided in the 1982 National Resources Inventory (NRI). Note that this land base totals roughly 420 million acres, almost half of which is in land group 3. The next column shows set-aside projections by land group. The column total (36.3 million acres) was based on U.S. Department of Agriculture (USDA) projections (as of the summer of 1986) for 1990. After deducting approximately 40 million acres of conservation reserve, we computed the 1990 land base (the final column in table 1) to be 343.4 million acres.

[2] The summary function technique described on pp. 5-7 produces an approximation to the LP as a function of the objective coefficients. In this application we construct a summary that is a function of right-side variables, that is, constraints on land and demand levels. Hence, we applied the summary function technique to the dual formulation of the CARD model *(3)*.

[3] Relative input prices and yields are left at the 1982 levels used in the recent application of the CARD model to an analysis of the Resources Conservation Act *(5)*. Because yields will probably be higher in 1990, the marginal cost associated with projected demands for that year will be exaggerated.

Table 1—Land groups, total acreages, and projected distribution across set-aside and conservation reserve

Land group	Capability classes[1]	Erosion potential	Average U.S. corn yield[2]	1982 NRI	Set-aside[3]	Conservation reserve[4]	1990 land base[5]
			Bushels per acre			*Million acres*	
1	I, IIWA, IIIWA	Low	109	69.4	1.9	0	67.5
2	IIW/S/C, IIIW/S/C, IVW/S/C	Low	67	106.5	14.9	5.4	86.2
3	IIE, IIIE, IVE, RKLS <50	Medium	97	194.6	16.7	17.6	160.3
4	IIE, IIIE, RKLS >50	High	85	22.0	1.5	6.4	14.1
5	IVE, RKLS >50	High	79	9.6	.8	2.9	5.9
6	V, VI, VII, VIII	High or low	37	17.3	.5	7.4	9.4
Total				419.4	36.3	39.7	343.4

[1]Suffix denotes dominant limitation. C = climatic; E = erosion; S = shallow, droughty, or stony soil; W = wetness; WA = wetness, but adequately treated.
[2]1977 yields are shown here only to illustrate differences in productivity between land groups. U.S. average corn yield in 1977 was 102 bushels per acre; source: *(7)*.
[3]Based on estimated distribution in 1983; source: *(2)*.
[4]Based on 3T criterion (land eroding at more than three times the soil loss tolerance level) for first 2 years (15 million acres), followed by 2T for the last 3 years (25 million acres).
[5]1982 NRI (National Resources Inventory) acreage less set-aside and CRP (Conservation Reserve Program).

Table 2—Actual distribution of commodity and set-aside acreage, by production region, 1983 and 1990

Item	Corn	Sorghum	Barley	Oats	Wheat	Cotton
				Percent		
Production region:						
Northeast	2.8	0.1	0.3	4.2	0.3	0
Lake States	18.4	.1	14.9	15.3	6.3	0
Corn Belt	48.1	8.4	0	.9	5.7	1.4
Northern Plains	17.1	45.7	37.6	62.3	39.1	0
Appalachia	5.4	1.4	.4	.4	3.0	2.7
Southeast	3.4	2.0	.2	1.9	2.3	5.2
Delta	.1	2.5	0	.1	2.7	19.1
Southern Plains	1.8	33.0	.5	4.0	20.3	56.7
Mountain	1.4	6.6	33.0	9.0	14.9	5.2
Pacific	1.5	.2	13.1	1.9	5.4	9.7
Total	100.0	100.0	100.0	100.0	100.0	100.0
				Million acres set aside		
Year:						
1983	32.2	5.7	1.1	0.3	30.0	6.8
1990 (projected)	12.6	2.0	1.6	0.3	17.0	2.8

Source: Based on data provided by the Agricultural Stabilization and Conservation Service, U.S. Department of Agriculture.

Distributing Set-Aside and Crop Acreage

The procedures for estimating set-aside and conservation reserve acreage, by land group and by region, are of central importance to our study and deserve further explanation. The distribution of set-aside by land group is based on national survey results from 1983 *(2)*. The regional distribution of set-aside acres was based on the actual distribution for 1983 (table 2). However, set-aside projections by crop for 1990 differ from 1983. Because different regions produce crops in different proportions, the proportions of total set-aside acres by region will also differ from 1983.[4]

The distribution of conservation reserve acreage by land group and region was based on the following assumptions:

(1) During the first 2 years of the conservation reserve (15 million acres), only land with an erosion potential in excess of 3T (three times the soil loss tolerance level) was eligible.

(2) During the last 3 years of the CRP (25 million acres), the eligibility criterion was relaxed to 2T.

(3) Eligible land is withdrawn proportionally across market regions and eligible land classes.[5]

Table 3 shows projected output levels for 1990 by crop. They are compatible with the ERS baseline projections as of the summer of 1986. Note that corn output is about 1 billion bushels below its 1986 level. Of course, these projections are subject to continual adjustment, and part of our task was to ascertain the effect of unforeseen changes in the level of demand for one or more of these crops.

Construction of the Summary Function

The summary function technique produces a local, differentiable approximation to the optimal objective of an LP as a function of the objective coefficients. In the case of a cost-minimizing LP, with prices of inputs as

[4] The set-aside adjustment scheme proceeds as follows. First, we computed the percentage set aside for each crop in each of the 10 USDA production regions for 1983 from table 2. Second, we used projected 1990 set-aside by crop to compute the 1990 set-aside in the 10 production regions. Third, we used the 1983 set-aside shares by land type (for 1990). Fourth, we used the land base to distribute proportionally the set-asides in the production regions across the 31 market regions in the model.

[5] This assumption of proportionality is problematic. Because of the current structure of commodity programs, relatively less than proportionate acreage from the Corn Belt has entered the CRP *(4)*. Thus, our analysis here will likely overstate the program's effect on corn prices. Of course, any changes in the commodity programs before 1990 could again change the mix of land entering the CRP, possibly reversing this effect. Behavioral equations governing the levels of the CRP by land group and region would ideally be used. Such complexity is beyond the scope of our study.

Table 3—Projected output levels, by crop, 1990

Crop	Quantity
	Million bushels
Corn	7,350
Wheat	2,475
Soybeans	2,113
Oats	532
Barley	627
Sorghum	868
	1,000 bales
Cotton	11,900
	1,000 tons
Corn silage	140,000
Sorghum silage	10,000
Legume hay	100,000
Nonlegume hay	80,000

the objective coefficients, this approximation would be expressed as a function of input prices. When evaluated for given levels of input prices, the value of the summary function approximates the minimum level of costs. The levels of the inputs associated with the minimum costs are also of interest. When one uses a standard envelope result, the first derivative of the summary function with respect to an input price is equal to the optimal level of input use. Thus, the summary function may be viewed as an approximate substitute for the LP. The method is general and may be applied to any LP.

The summary function is constructed by a two-step process. (Technical details are found in *(12)*.) First, a piecewise linear summary of the true optimal response function is constructed. The "base case coefficients" define the point about which the approximation is constructed. Although it is difficult to determine the entire surface of optimal objective function values as a function of objective coefficients, it is straightforward to determine the optimal objective values associated with a range of objective coefficients lying on a straight line. Hence, the experimental design of a summary function analysis consists of setting the base case coefficients, defining a set of directions for changing those coefficients, and defining limits for the changes for each direction.[6] Because a given basis will be optimal for a range of objective function coefficients, each LP evalua-

[6] To illustrate, consider the following example. Let the base coefficients for a two-variable LP be (2,3). Let one of the directions be given as (−1,1), and let the limits for change associated with that direction be from −0.1 to 0.1. Then, the LP response would be constructed for the line segment of objective coefficient variables $(2-\alpha, 3+\alpha)$ for values of α between −0.1 and 01.

tion yields a line segment of optimal objective function values and activity levels.[7]

The second step in the construction of the LP summary involves estimating parameters for the differentiable approximation. Once a functional form is chosen, the parameters are selected so as to minimize the square of the difference between the true optimal LP response to the objective coefficients and the differentiable summary. Because the LP responses observed are for line segments of data, the estimation problem involves solving a nonlinear programming problem whose objective function is an infinite sample generalization of a least-squares curve-fitting problem.

Experimental Design and the Piecewise Linear Function

Our objective is to summarize the LP's responses to variations in national demands as well as to changes in CRP acreage. These responses amount to changes in right-hand sides for the CARD model. Because the summary function method is designed to build summaries with respect to the objective coefficients, it was necessary to work with the dual formulation of the usual cost-minimization problem *(3)*. As a result, the primal right-hand-side coefficients became objective coefficients in the dual problem. The summary was then created as a function of these demand and acreage levels.

To limit the amount of numerical effort, we restricted the number of variables entering the summary function. We chose to make the summary a function of the national demands for corn, wheat, soybeans, and a residual category called "other crops." We also included the level of conservation reserve acreage in the function. These variables were each perturbed one at a time over the range from 75 percent to 125 percent of the base values for the national crop demands and the CRP. We then constructed the piecewise linear summary using a maximum of five LP evaluations per direction. The selection of individual sample points is determined endogenously by the summary function algorithm (see *12* for details).

Estimation and Differentiable Summary Function

We chose the differentiable summary function fitted to the piecewise linear response surface to be translog in form, which is the most popular of the class of flexible functional forms meeting the criteria outlined by Fuss and others *(6)*. Rather than estimating the shadow cost function itself, we estimated a set of share equations. The individual marginal cost share equations and the associated R^2's (explained variation divided by total variation) follow: corn (0.77), soybeans (0.70), wheat (0.76), other crops (0.73), and conservation reserve acreage (0.62). Together with base case costs, these share equations provide the parameters for the translog summary function given in table 4.

The translog estimates must be converted into flexibilities before they can be readily interpreted (table 5). These flexibilities describe the effect *(at the base point)* of a 1-percent change in any of the quantities on the marginal cost of supplying more output or CRP acreage. Several obvservations are noteworthy. First all the flexibilities are positive, indicating that more output requirements or less available land always boost all marginal costs. Second, the largest numbers appear in the last row of table 5, which means that the marginal cost of bidding more land into the CRP is extremely sensitive to output levels.[8] For example, the

Table 4—Fitted summary function

Functional form:

$$\ln Z\,(Y, CRP) = A_O + A_Y^T \overline{Y} + A_C \overline{CRP}$$
$$+ 1/2\ \overline{Y}^T A_{YY} \overline{Y} + 1/2\ A_{CC} \overline{CRP}^2 + 1/2\ \overline{CRP}\ A_{CY} \overline{Y}$$
$$+ 1/2\ \overline{Y}^T A_{YC} \overline{CRP}$$

where $\overline{Y}^T = (\ln y_C, \ln y_S, \ln y_W, \ln y_O)$
$\overline{CRP} = \ln CRP$; and
y_C, y_S, y_W, and y_O are outputs of corn, soybeans, wheat, and other crops, respectively; Z (Y, CRP) is the total cost; and CRP denotes total acreage in the Conservation Reserve Program.

Fitted parameter values:

$A_O = 17.269$, $A_C = .034$, and

$$A_Y^T = [0.379\quad 0.257\quad 0.223\quad 0.476]$$

$$\begin{bmatrix} A_{YY} & A_{YC} \\ A_{CY} & A_{CC} \end{bmatrix} = \begin{array}{ccccc} C & S & W & O & CRP \\ \end{array}$$
$$\begin{bmatrix} .454 & .033 & -.018 & .075 & .054 \\ & .367 & -.002 & .100 & .054 \\ & & .270 & .029 & .026 \\ \text{Symmetric} & & & .801 & .110 \\ & & & & .057 \end{bmatrix}$$

C = corn; S = soybeans; W = wheat; O = other crops; and CRP = Conservation Reserve Program.

[7]This aspect of the problem is similar to LP "cost ranging."

[8]The estimated change in CRP bid prices is based purely on the scarcity value of the land, which in turn is based on the potential productivity of the new CRP land. In early rounds of bidding for CRP contracts, the multicounty bid "caps" tended to determine the average bid levels. They have often exceeded cash rents by a considerable margin *(4)*. However, as more land enters the CRP, the scarcity value of the remaining land will rise (see fig. 1 and table 5), and bid caps may have to be raised to enroll additional acreage. Thus, the change in CRP bid prices reported here may be interpreted as the speed at which bid caps must be raised, once cash rents on remaining acreage have caught up with them.

Table 5—Marginal cost flexibilities[1]

Item	Change in marginal cost due to: 1-percent change in demand for— Corn	Soybeans	Wheat	Other crops	1-percent increase in CRP
	Percent				
Marginal cost commodity production:					
Corn	0.58	0.34	0.17	0.67	0.18
Soybeans	.51	.68	.21	.87	.25
Wheat	.30	.25	.44	.61	.15
Other crops	.54	.47	.28	1.16	.27
Marginal cost bidding for CRP land	1.96	1.84	.97	3.70	0.70

[1]Percentage increase in marginal cost due to increased demand or Conservation Reserve Program (CRP) land.

first number in the last row indicates that a 1-percent increase in the projected level of corn demand raises the marginal cost of CRP land by 1.96 percent. The last entry in this row predicts that a 1-percent increase in conservation reserve acreage raises the expected cost of bidding in the next CRP acre by 0.7 percent. Thus, at 40 million acres, the marginal cost of extending the CRP begins to increase sharply.[9]

The difference in the size of flexibilities across the first four columns of table 5 is a function of the absolute magnitude of output at the base point. Thus, they are largest in the "other crop" and corn columns, since a 1-percent increase in these demands places the greatest pressure on the land base. Although soybean and wheat acreages are similar in the base solution, an increase in the former has a greater impact on marginal costs because soybeans compete more intensely for acreage with the other three crop categories.

The final column in the flexibility matrix describes the shift in supply curves as more land is brought into the conservation reserve. The upward shift in marginal costs is considerably larger for soybeans than for corn or wheat. *If the effect of varying output levels on marginal costs is ignored,* this coefficient may be translated directly into a supply price change. That is, a 10-percent increase in the CRP, beyond 40 million acres, will cause supply price increases of 1.8 percent for corn, 2.5 percent for soybeans, 1.5 percent for wheat, and 2.7 percent for other crops.

[9]The scarcity value of additional CRP land is a function of the institutional constraints imposed on new enrollments. The results reported here do not impose the 25-percent maximum on land enrolled in any given county. Doing so would cut eligible acreage from 101 million to 70 million acres. Adding this constraint would make the rate of increase in CRP bid prices (as output and/or CRP acreage are increased (bottom row in table 5)) even higher.

Commodity Price Effects

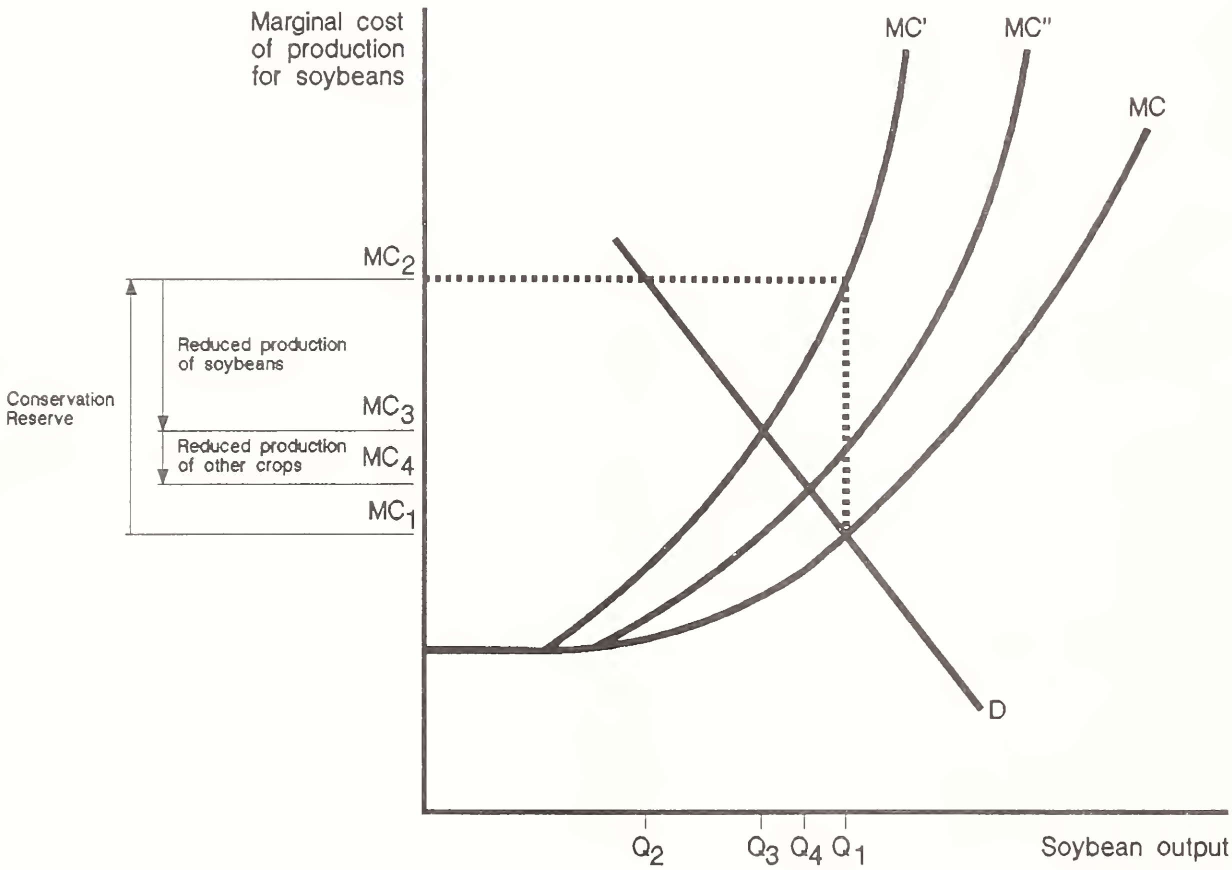
To project the likely consequences of extending the CRP in 1990, we must combine the marginal cost flexibilities already developed with information on commodity demands.

Figure 2 illustrates the relevant market interactions for soybeans. Here the discontinuous marginal cost relationships in figure 1 have been smoothed to reflect a continuous distribution of land types. The marginal cost of producing soybeans increases along MC as output moves onto less productive land. The initial equilibrium (the 1990 base case) is given by (Q_1, MC_1).

When we place additional acres under the CRP, the marginal cost curve shifts to MC′. (As noted above, the nature of this shift depends crucially on the productivity of the land withdrawn.) If the quantity demanded were unchanged, the projected increase in soybean's marginal cost (due to lower yields) would be $MC_2 - MC_1$. This difference is the measure obtained by solving the CARD LP model both with and without the CRP acreage available. However, since demand is not perfectly inelastic, the resulting market price for soybeans will not represent an equilibrium outcome. The quantity demanded will drop to Q_3, which in turn relaxes the pressure on the land base and lowers the marginal cost of production (MC_3).

Because the CRP raises prices and reduces the output of other crops as well, the curves in figure 2 will shift. In particular, the reduced competition for soybean land will shift MC′ out to MC″, further dampening the soybean price effect of the CRP (now only $MC_4 - MC_1$). (The demand curve will also shift with changes in the prices of competing commodities.) This type of cross-commodity interaction can be quite important, as shown in the estimates below.

Figure 2
Illustrating the feedback effect on yields and marginal costs



A Simple Equilibrium Model

Taking the partial derivatives of the shadow cost summary function (with respect to the output vector) yields a set of marginal cost equations:

$$\nabla_Y Z(Y^S, CRP, \overline{W}) = MC(Y^S, CRP, \overline{W}) = P^S \quad (1)$$

where P^S is the vector of supply prices for the four commodity groups, assuming competitive behavior. Note that these inverse supply functions explicitly incorporate information on all output levels (Y^S) and the level of the CRP, as well as input prices ($\overline{W}$: assumed here to be exogenously fixed). These functions provide a convenient summary of the supply side of the problem.[10] Furthermore, their continuously differentiable form makes them ideal for incorporation into an econometric model such as FAPSIM (*13*), thus permitting simultaneous solution of supply and demand conditions.[11]

We use a simplified model of commodity markets to capture the feedback effects from output to marginal costs shown in figure 2. The following three equations are added:

$$Y^D = G(P^D, \overline{P}^O) \quad (2)$$

$$p_i^S = p_i^D \text{ when } p_i^D > p_i^{TP}; \text{ and } p_i^S = p_i^{TP} \quad (3)$$

Otherwise (for all commodities i):

$$Y^D = Y^S \quad (4)$$

Equation 2 describes a vector of commodity demands as a function of a vector of endogenous prices (P^D) and any other relevant prices ($\overline{P}^O$ assumed fixed). Equation 3 describes pricing rules in the presence of target prices (p_i^{TP}). (Per-bushel deficiency payments for commodity i equal ($p_i^{TP} - p_i^D$).) Finally, commodity markets are assumed to clear. Thus, the results refer to a medium-run scenario over which no net stock accumulation occurs. Equations 1-4 may be solved for equilibrium quantities, prices, and deficiency payments, based on alternative levels of the CRP acreage.

[10] See (*10*) for a discussion of how the LP itself may be combined with an econometric demand system.

[11] Some further steps are desirable before this summary function is incorporated into a model such as FAPSIM. By summarizing the LP response with respect to feed grain and food grain set-aside acreage, one can vary the marginal cost of production as a function of program participation, which is endogenous to the FAPSIM framework.

In keeping with the local nature of the summary function approximation, the model is solved for percentage changes from the base (1990) values. Totally differentiating equations 1-4 and solving for the equilibrium percentage change in commodity market prices yields:

$$P^D = \{ [J - N * E]^{-1} M \} \text{ CRP} \tag{5}$$

where N is a matrix of marginal cost-output flexibilities, E is a matrix of demand elasticities, and M is the vector of marginal cost-CRP flexibilities. J is the identity matrix when $p_i^D > p_i^{TP}$ for all i, and its j^{th} diagonal element becomes zero when $p_j^{TP} > p_j^D$. CRP denotes the specified percentage change in conservation reserve acreage.

The matrices N and M are generated by our summary function and have been provided in table 5. However, we have not yet specified the matrix of farm-level demand elasticities. Although individual elements are available in the literature, there is little consensus about the nature of the matrix E. (Brandow's work in the late fifties is an exception (*1*).) We have focused our efforts on corn, soybeans, and wheat. The 3×3 matrix of demand elasticities in table 6 is based on the model presented by Hertel and Tsigas (*9*), using the methodology developed by Hertel, Ball, Huang, and Tsigas (*8*). These elasticities incorporate estimated price responsiveness in livestock, prepared feeds, and export and consumer demands. Export demand elasticities are taken from (*14*). They may be viewed as medium-term elasticities, and they reflect adjustment in *all* factor and product markets. Individual crops compete for crop capital and farm labor, but competition for land has not been permitted. (This aspect is already captured by the flexibility matrix.) Note that the own-price elasticities in table 6 range from −0.69 to −0.86 and that significant cross-price effects are present. The cross-price elasticities derive from competition among crops in domestic feed use as well as in export markets (see (*14*) for a discussion of the latter effect).

Table 6—Aggregated demand elasticities[1]

Commodity	Corn	Soybeans	Wheat
		Elasticity	
Corn	−0.858	0.092	0.080
Soybeans	.189	−.701	.038
Wheat	.381	.077	−.688

[1]The following correspondence between commodity groups has been assumed: feed grains=corn, oilseeds=soybeans, and food grains=wheat. These farm-level demand elasticities are computed from the 39-sector general equilibrium model of the U.S. economy presented in (*9*).

Results

Table 7 summarizes projected commodity market effects of increasing the conservation reserve by 10 percent beyond the 40-million-acre base. Two alternative assumptions regarding demand-supply interactions are explored. Potential interactions with commodity programs are also examined in this table. In the first two columns of table 7, target prices are assumed to be nonbinding. Thus, supply price equals demand price. By setting the marginal cost-output flexibility matrix equal to zero, we can eliminate the feedback from output to yields. This procedure is roughly equivalent to solving the LP model once with a given level of demand, using the resulting yield (marginal cost) information to predict commodity supply prices. (It is analogous to the method employed in (*15*).) When the feedback effect from output to yields is ignored, prices increase by 1.8 percent for corn, 2.5 percent for soybeans, and 1.5 percent for wheat. Equilibrium quantities of corn and soybeans drop by 1.2 and 1.4 percent. Output of wheat drops by only 0.2 percent because of strong cross-price effects in demand. This output information may be used to predict the cost effect of bringing the next acre of land into the conservation reserve. The last number in the first column of table 7 shows that this increase will be relatively small (2 percent) when feedback effects are ignored.

The next column of table 7 introduces the feedback effects (but not target prices). By comparing these results with those presented in the first column, we can see that ignoring the feedback from output to yields leads to an overstating of the commodity price effects

Table 7—Impact of adding 4 million acres to the conservation reserve in 1990

Item	$P^S = P^D > P^{TP}$		$p_i^{TO} > p_i^D$: Corn and wheat[1]	
	No feedback effect on yields	Complete feedback effect	Complete feedback effect	
			P^S	P^D
		Percent		
Prices:				
Corn	1.8	1.1	0	3.7
Soybeans	2.5	1.5	.9	.9
Wheat	1.5	1.0	0	4.6
Quantities:				
Corn	−1.2	−.7	−2.7	
Soybeans	−1.4	−.8	.2	
Wheat	−.2	−.2	−1.6	
Marginal cost CRP	2.0	3.9	.4	

[1]Change in deficiency payments: corn=8.1 cents/bu (assuming p_C^{TP}=$2.75/bu, p_C^D=$2.20/bu); wheat=14.1 cents/bu (assuming p_W^{TP}=$4.00/bu, p_W^D=$3.20/bu). Output changes assume no change in set-aside acreage.

of enlarging the CRP.[12] This error may in turn be decomposed into that associated with movement ($MC_2 - MC_3$) down the marginal cost curve (MC′) in figure 2 and with the outward shift ($MC_3 - MC_4$) of this curve to MC″. For example, for soybeans, the 2.5-percent price hike under the no-feedback assumption is reduced in turn by -0.7 percent (own-output effect) and -0.3 percent (cross-output effect), causing prices to rise by only 1.5 percent. Finally, note that incorporating these feedback effects also increases projected output, which doubles the rate of change in the marginal cost of adding to the CRP. In this case, moving from 40 million to 44 million acres increases estimated bid prices by 3.9 percent.

The final column in table 7 illustrates the effect of binding target prices for wheat and corn under the extreme assumption that program participation rates do not respond to increases in market prices. Thus, set-aside acreage remains at the levels shown in table 1. In this case rising marginal production costs, combined with fixed target prices, cause much larger reductions in corn and wheat output. As a result, market prices must rise more than they would in the absence of target prices, and deficiency payments shrink by 8.1 cents/bushel for corn and 14.1 cents/bushel for wheat. These larger output reductions further shift the soybean supply curve to the right (that is, beyond MC″). Because the market prices of corn and wheat rise by so much more than the market prices of soybeans, there is a strong rightward shift in the farm-level demand for the latter. Therefore, equilibrium output of soybeans actually rises, despite the increased conservation reserve acreage ($Q_4 > Q_1$ in fig. 2).

Of course, participation rates in the corn and wheat programs are expected to drop in response to higher market prices, reducing set-aside acreage and further shifting these program crops' marginal cost curves to the right. In effect, the Government is substituting one form of program payment for another. The degree to which these two effects offset each other depends on the responsiveness of program participation rates to market prices, as well as the relative productivity of set-aside acreage.

Conclusions

We have presented some estimates of the expected effects on marginal costs of production of extending the CRP beyond the minimum of 40 million acres mandated for 1990. We have also examined the likely effect on CRP bid prices. A 10-percent increase in program acreage could raise the marginal cost of adding to the CRP by as much as 7 percent. Thus, as attempts are made to extend the CRP, it is important to take into account the fact that per-acre rental costs will rise sharply at the margin. Both types of marginal costs are shown to be extremely sensitive to the level of demand projected for 1990. A 10-percent higher corn demand would raise the marginal cost of corn production 5.8 percent, while the marginal cost of renting CRP land would increase by almost 20 percent.

We combine this supply information with a set of farm-level demand elasticities to estimate the likely changes in corn, soybean, and wheat prices if the CRP is increased by another 10 percent. If 1990 market prices exceed target prices, soybeans are affected most; their price rises 1.5 percent. This estimate is much lower than would have been obtained in the absence of multicommodity feedback effects. As a result, previous studies ignoring the feedback from output to yields have overstated the degree of price support, which in turn understates the rate of increase in bid prices as acreage is added to the CRP.

Estimating the interaction effects between the CRP and traditional price and income support programs is more difficult. As CRP acreage is withdrawn, marginal costs and, hence, market prices tend to rise. If set-aside acreage is held constant, the output of program crops is lowered considerably. However, the supply-restraining features of the program will be blunted to the extent that adding to the CRP reduces program participation and, hence, set-aside acreage. Estimation of these program interactions should be a high priority for future research.

[12]These numerical results use only a portion of the flexibility matrix in table 4. The row and column relating to "other crops" are omitted because a comparable demand matrix is not available. If the full (4×4) output flexibility matrix were utilized, the cross-output effects would be even greater, which would further dampen the price increases.

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Estimating the Costs of Conservation Compliance

Alexander Barbarika, Jr., and Michael R. Dicks

Abstract. *The conservation compliance provision of the 1985 Food Security Act requires farmers to implement conservation plans on highly erodible cropland as a prerequisite for eligibility in agricultural commodity programs. Reducing erosion to the soil loss tolerance level on about 46 million highly erodible cropland acres needing treatment would cost almost $700 million annually, an average of $15 per acre.*

Keywords. *Conservation compliance, soil erosion, Highly Erodible Land Subtitle, 1985 Food Security Act.*

Crop production on highly erodible soils will continue to be the target of increasing interest for the remainder of the decade as conservation provisions of the 1985 Food Security Act are implemented. These provisions are designed to prevent U.S. Department of Agriculture commodity programs from contributing to soil erosion problems. By encouraging the cultivation of erodible soils or erosive crops, commodity programs may be contributing to soil erosion, an outcome inconsistent with overall USDA goals (*5, 10*).[1]

The conservation compliance provision in the Highly Erodible Land (HEL) Subtitle of the 1985 Food Security Act is of major importance to farmers. The provision requires conservation plans to be implemented on highly erodible cropland as a prerequisite for access to Government commodity program benefits. Although some 118 million acres are considered highly erodible, the compliance provision will affect fewer than 46 million acres because roughly 35 million acres are currently in compliance or are not considered cropland by the definition in the HEL subtitle, while another 37 million acres are likely to be enrolled in the Conservation Reserve Program or could be adequately treated with conservation tillage at no cost increase.

Highly erodible cropland is defined in the HEL subtitle as land under cultivation of an annually produced commodity with an erodibility index of 8 or greater. The erodibility index, a measure describing the relative susceptibility of a soil to erosion damage, is created by the division of a measure of the physical attributes of a soil's erodibility by the soil loss tolerance level (T). The greater the erodibility index, the more susceptible the soil is to erosion damage (*2*).

Implementation of conservation plans must begin by 1990, when farmers must decide between (1) placing their highly erodible cropland in the Conservation Reserve, (2) implementing conservation plans and continuing to farm the land, thereby retaining eligibility for commodity program benefits, or (3) farming without conservation plans and losing eligibility for commodity program benefits. Farmers will have to weigh the value of their commodity program benefits against compliance costs.

The level of erosion on highly erodible cropland that will be considered acceptable under the HEL provision is nonspecific. The final rules and regulations governing implementation of this provision note that the T and 2T (twice the soil loss tolerance level) limitations for conservation plans and conservation systems may be too restrictive in some instances. Thus, USDA has provided flexibility in the selection of locally approved conservation plans and systems. The conservation systems are designed to achieve substantial reductions in soil erosion, taking into consideration economic and technical feasibility and other resource-related factors (*12*). The Soil Conservation Service has determined that roughly 85 percent of the cropland subject to conservation compliance can be treated to T. The balance of the highly erodible croplands will continue to erode slightly above T when used for the production of agricultural commodities.

Thus, we assume that farmers will generally be required to reduce the level of erosion on highly erodible cropland to T to comply with the provisions of the HEL subtitle. T is basically the rate at which the soil is formed under natural conditions. Because some leeway will be provided where compliance to T poses economic hardship to the farmer, we estimate costs at both T and 2T compliance levels to illustrate the effect of relaxing the required compliance level.

How Can Compliance Be Achieved

Reducing erosion on highly erodible cropland can be achieved by (1) changing the current crop rotation, (2) moving from conventional (fall or spring plowing) to conservation tillage, or (3) implementing conservation practices.

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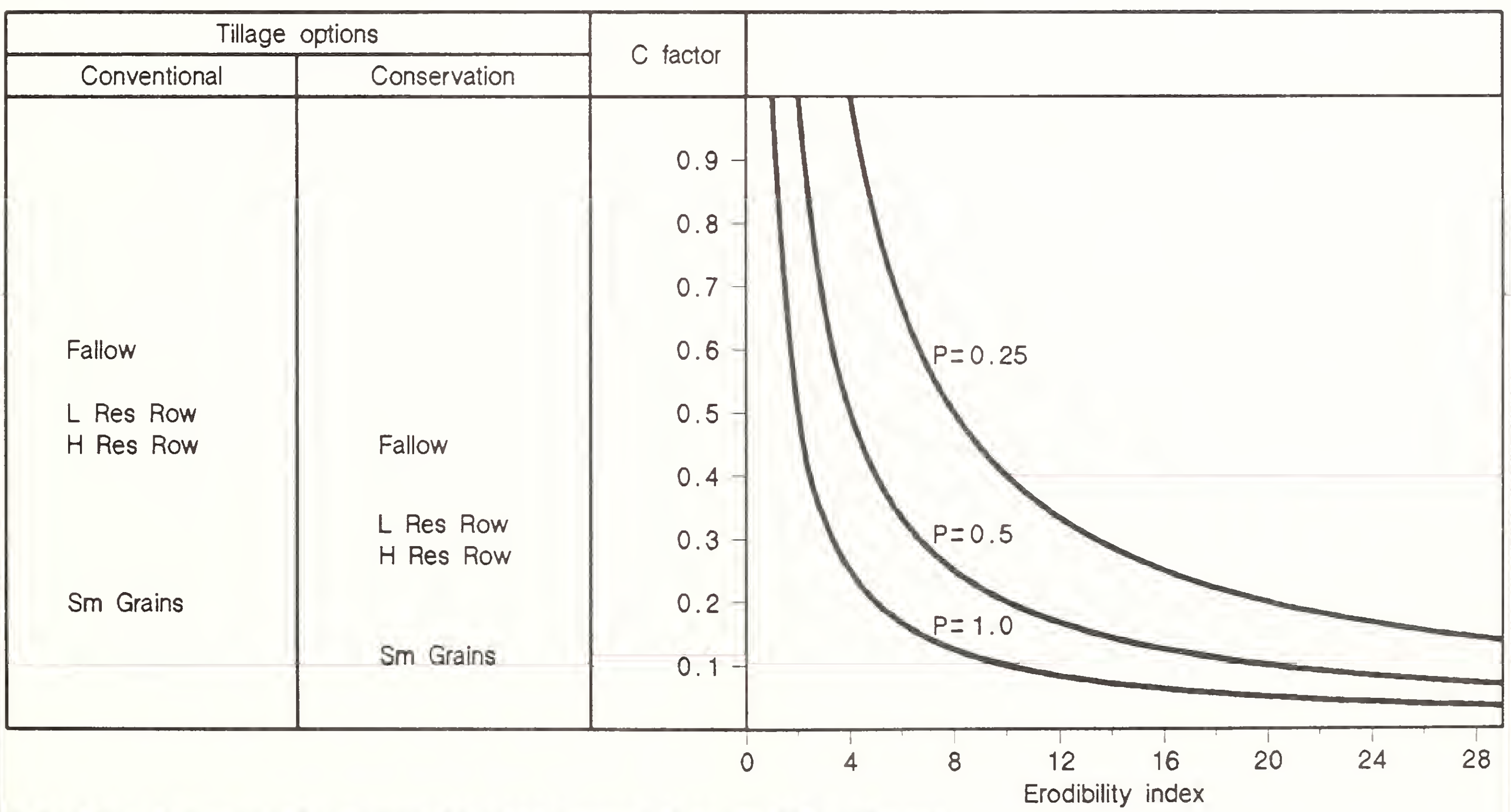
[1]Italicized numbers in parentheses refer to items in the References at the end of this article.

Putman examined the relationship between erosion, erodibility, crops, and tillage practices (*8*). His nomograph (fig. 1) illustrates that the more susceptible a field is to erosion (the higher the erodibility index), the more difficult it is to reduce erosion to T by changing the crop rotation or tillage pratices. The left side of the nomograph describes four crop types (fallow, high-residue, low-residue, and small grains) under two options for tillage practice. The corresponding cover factor (C) for each crop type and tillage combination is shown on the vertical axis. The C factor reflects the effect of cropping practices on erosion and is the ratio of the soil loss as the land is actually being cropped to the corresponding loss if the land were clean-tilled fallow (*13*). The erodibility index, along the horizontal axis, multiplied by the C factor indicates the actual rate of erosion in proportion to the soil loss tolerance level. Thus, the relationship between the erodibility index and the C factor forms an isoerosion curve. The points along each of the three curves represent an erosion rate equal to T. The nomograph shows, for example, that on soils with an erodibility index of 8, T can be achieved in the absence of conservation practices (the line corresponding to P = 1.0), only when small grains are cropped and conservation tillage is used.

The third means of reducing erosion, conservation practices, is reflected in the nomograph by the different values of P, the support practice factor. The P factor is the ratio of the annual soil loss with a conservation practice in place to the annual loss that would occur without the practice (*13*). Applying terraces or windbreaks, strip cropping, or contours, which reduce the P factor, reduces the C factor required to maintain the relative level of erosion at some prescribed level for any given erodibility index. The application of a conservation practice shifts the isoerosion curve on the graph outward. This process is demonstrated in the nomograph for various levels of P (0.25, 0.5, 1.0) where the isoerosion curve is drawn for all points at which the level of erosion is just equal to the soil loss tolerance level. As with the C factor, the greater the effect of the conservation practice on reducing erosion, the lower the P value.

The nomograph describes the tradeoffs between conservation practices, tillage practices, and crop types that are required to reduce either wind or sheet and rill erosion to a specific level. However, when both wind erosion and sheet and rill erosion occur, the effect on erosion of substituting among crop types is not easily

Figure 1
Soil erosion nomograph, showing effect of changing P factor



L Res Row = Low-residue row crops (soybeans, cotton, peanuts, and sunflower)
H Res Row = High-residue row crops (corn and sorghum for grain)
Sm Grains = Small grains (barley, oats, wheat)

defined. Practices that may affect sheet and rill erosion may not affect wind erosion, and vice versa. Thus, in areas such as the Great Plains where wind and sheet and rill erosion occur, treatment costs may be underestimated.

Each method of reducing erosion has an associated cost. Modifying the current cropping rotation will reduce net returns in most cases. Changing from conventional to conservation tillage often reduces average annual production costs. However, the change may require new equipment and make existing equipment obsolete, thereby offsetting some production cost decreases. Implementing a conservation practice requires either direct capital outlays (terrace, windbreaks) or increases in variable costs of production (strip cropping, contouring) or both. Our procedure allows for changing tillage practices and implementing conservation practices, but not for changing crop rotation or land use.

We have omitted the estimation of rotational changes in our determination of compliance costs for several reasons. First, the number of possible rotations for any given area is unlimited. Although several linear programming models currently in use include rotations in their formulation, they represent only the most frequently used rotations in any given area, not those that may be used to meet compliance.

Second, rotational changes that are made to meet compliance are dynamic. That is, producers select rotations in response to relative prices of potential crops. Where the production of more erosive crops is reduced and the production of less erosive crops increases sufficiently to affect the relative price of these crops, a new rotation may be used. Furthermore, because the relative prices of more erosive and less erosive crops affect the selection of a rotation, other variables that can influence crop prices can also influence the selection of a rotation.

Data and Methods

Two cost-of-treatment functions are used in conjunction with the 1982 National Resources Inventory (NRI) to estimate the cost of reducing erosion on highly erodible U.S. cropland to T. Each NRI sample point was first checked to see if the land it represented would be eligible for enrollment in the Conservation Reserve Program (CRP). Using information from the first five CRP signups, we estimated total eventual CRP enrollment per county. The CRP-eligible NRI sample points were then randomly seleted for enrollment until each county's acreage limit was reached. The lands selected were assumed to represent an eventual 45-million-acre CRP and to have no compliance costs.

Second, conservation tillage adoption was simulated on all sample points presumed to be faced with compliance in 1990. If the RCA/CARD model budgets associated with the sample points indicated that cost savings would probably occur, then the NRI sample point was "treated" with conservation tillage at no cost. The NRI-reported soil erosion rates were adjusted downward to reflect the resulting soil savings on the sample points. The amount of adjustment was estimated based on USDA's Conservation Reporting and Evaluation System (CRES) and NRI data.

Using CRES-derived cost functions, we estimated the costs of reducing erosion to T and 2T on highly erodible land requiring treatment after a simulated enrollment in CRP and adoption of conservation tillage. Finally, using the NRI-provided expansion factors, we expanded treatment costs to estimate costs of conservation compliance at the regional and national levels.

CRES Data

USDA's 1985 CRES provides field-level estimates of soil savings and both public and private expenditures associated with conservation programs of the Soil Conservation Service (SCS) and the Agricultural Stabilization and Conservation Service (ASCS). These programs include the Agricultural Conservation Program (ACP), Great Plains Conservation Program (GPCP), Rural Clean Water Program (RCWP), and Conservation Technical Assistance (CTA). Information collected on fields treated in conjunction with these programs includes descriptions of practices implemented, implementation costs, effect on soil erosion, acres affected, and land use before and after treatment.

We converted installation costs for multiyear practices to annual costs, using a discount rate of 4 percent and appropriate service lives as provided by ASCS. Estimates of annual operation and maintenance costs were provided by SCS. Technical assistance costs, valued at $62.50/hour (field time) were also annualized (*11*). The technical assistance is provided by SCS under the CTA program at no cost to the farmer. However, whether incurred by the farmer or SCS, costs for technical assistance are still costs and are included in our estimate of treatment costs. We used the total of the annual installation, operation, maintenance, and technical assistance costs divided by the acres treated for each observation to estimate the annual per-acre treatment cost. Erosion rates in tons per acre per year (TAY) before and after treatment came directly from CRES: we calculated the erosion rates with the Universal Soil Loss Equation for sheet and rill erosion (*13*) and the Wind Erosion Equation for wind erosion (*14*).

Technical assistance hours were not reported on most CRES records. Only certain counties (about 330) reported the number of hours of technical assistance provided by SCS technicians. Data from these counties were used in a regression model to predict hours used by farmers in other counties. Hours per practice required in each farm production region for each type of practice installed, in fields with and without gullies, were hypothesized to be a function of the log of the acres served. The hypothesis was tested, and data from the 330 reporting counties were used to estimate the coefficients. The overall R-square was 0.45, and the significance level for all three categories of dummy variables (region, practice, and gully presence) was 0.0001. The estimated coefficients were used to predict the amount of technical assistance provided to farmers in the nonreporting counties. Table 1 shows the range in regional average hours per acre for selected conservation practices, based on the estimated coefficients.

Production cost adjustments resulting from the implementation of conservation tillage were not available from the CRES data. Estimates of the average differences in net returns between conservation and conventional tillage practices by State and soil resource group were generated from the RCA/CARD model (*9*). They were used in place of the CRES-reported conservation tillage costs. This procedure resulted in negative costs where adoption of conservation tillage would, on average, have reduced production costs.

We estimated two treatment cost functions using CRES records meeting the following criteria: (1) primary purpose of assistance was erosion control; (2) land use before and after treatment was cropland; (3) erosion rate before treatment was greater than T; (4) sheet and rill and/or wind erosion was reduced; (5) costs did not decline with a shift from conventional to conservation tillage; and (6) cost sharing with ACP or RCWP was provided. These selection criteria generally ensure that annual treatment costs per acre can be calculated, and only the observations that represent cropland treated for erosion are used. Almost 37,000 observations from the 1985 CRES met the criteria.

Table 1—Estimated technical assistance hours per acre for selected conservation practices[1]

Conservation practice	Hours per acre[2]
Conservation tillage	0.02-0.38
Cover crop	0 - .08
Contour farming	.33- .69
Dam	.74-1.09
Diversion	.87-1.23
Irrigation water management	.80-1.15
Permanent vegetative cover	0 - .26
Sediment retention	1.14-1.50
Stripcropping	.70-1.05
Terraces	1.53-1.89
Tree planting	0 - .15
Windbreaks	.39- .75
Grass waterways	.38- .74

[1]Based on Conservation Reporting and Evaluation System data from the 330 reporting counties.

[2]Range in regional averages, 10-acre field, no gullies.

Criteria 1-5 are designed to eliminate observations atypical of treatment for conpliance. Many practices are installed for reasons other than soil conservation. If they were installed for moisture conservation or for production costs savings, then the CRES-reported costs would likely overstate (or understate) the true cost of reducing soil erosion. These other factors affecting treatment costs could ideally be included in the regression model. Criterion 6 is the result of technical problems with the CRES data. Reliable estimates of the service life of the practice mix could be derived only from ACP- and RCWP-related installations. Estimates of service life are necessary to calculate annual costs, the dependent variable in the cost functions.

Cost Function Estimation

We assumed that the CRES data meeting the six criteria represent a cross-sectional set of observations on soil erosion abatement costs. The annual per-acre treatment costs were hypothesized to be a function of the current erosion rate (a proxy for erodibility), the level of treatment (tons saved per acre), the type of erosion, the size of field treated, and the regional location. Two separate cost functions were estimated from ordinary-least-squares regression. We estimated the parameters for the first function using all the CRES records meeting the six criteria. We estimated the second set of parameters using a subset consisting of all the selected CRES records except those describing conservation tillage implementation. Function 1 was used to predict treatment costs on NRI sample points where conventional tillage was used in 1982. Cost function 2 predicts costs where conservation tillage was used in 1982. This procedure prevents conservation tillage from being used twice. The estimated equations are as follows:

$$\begin{aligned} CAY = {} & Ir + \underset{(0.50)}{3.07}*TYPE + \underset{(0.021)}{0.551}*SAVED + \underset{(0.0011)}{0.0133}* \\ & SAVED^2 - \underset{(0.0011)}{0.0141}*SAVED*RATE + Dr*IACRES \qquad R^2=0.26 \end{aligned} \tag{1}$$

(se)

$$\begin{aligned} CAY = {} & Ir + \underset{(0.52)}{4.24}*TYPE + \underset{(0.022)}{0.662}*SAVED + \underset{(0.0011)}{0.0160}* \\ & SAVED^2 - \underset{(0.0011)}{0.0170}*SAVED*RATE + Dr*IACRES \qquad R^2=0.26 \end{aligned} \tag{2}$$

(se)

where:

CAY = annualized treatment cost per acre;
Ir = intercept for farm production region r (r = 1, 2,. . . 10);
TYPE = dummy variable that changes intercept,
= 0 if erosion is sheet, rill, and wind,
= 1 if erosion is sheet and rill only;
SAVED = reduction in erosion (tons per acre per year) due to treatment;
RATE = erosion rate in tons per acre per year;
IACRES = inverse of acres affected by treatment; and
Dr = coefficient associated with IACRES for region r.

We estimated the intercepts (Ir) and field size coefficients (Dr) separately for each region using region-specific dummy variables. Table 2 shows the regional intercept and field size coefficient estimates and the significance levels. Comparison of predicted costs indicates that, when conservation tillage is assumed already in use and, therefore, not an option (function 2), treatment costs are slightly higher.

Field size is a significant factor explaining variation in annual per-acre treatment costs, which probably reflects the effect of spreading fixed costs over more acres. The possibility that less costly practices were used on larger fields was not explored. Ervin and others (*4*) found a similar negative relationship between farm size and cost per acre. Costs differ significantly, depending on geographical location and type of erosion treated. Farmers in the West spend less per acre than farmers in the East (table 2). When both water- and wind-caused soil erosion are treated (TYPE = 0), per-acre costs are lower than when only water-caused erosion is affected. The few CRES records that described abatement of only wind erosion were not used to estimate the equations.

The positive coefficients on the SAVED and SAVED-squared variables indicate that, for identically eroding fields, the cost per ton of erosion reduced will increase (at an increasing rate) as the amount of soil saved increases. Costs are lower to save the first ton of soil than the last. The negative sign on each equation's SAVED*RATE interaction coefficient indicates that the more erodible the land, the lower the average cost per ton saved. Consider two fields, one eroding at 25 TAY and the other eroding at 10 TAY. The negative coefficients for the interaction terms indicate that reducing erosion by 5 TAY on the 25 TAY field will cost less than reducing erosion by 5 TAY on the 10 TAY field. Figure 2 plots the predicted costs using function 1. The three lines represent the predicted cost of treating fields with different pretreatment erosion rates. The cost lines for other regions, field sizes, and erosion types have the same slopes, but different intercepts.

Results

The low coefficients of determination would be a problem if important variables were omitted from the regression models or if the functional forms specified were inappropriate. Neither problem is believed to be present to a significant extent. The cross-sectional nature of CRES and the fact that reported costs are based on various sources (actual observation, engineering-based estimates, and county technicians' best guesses) partly explain the low R^2's. Furthermore, CRES installations often had other purposes that could introduce sources of cost variation not accounted for in the model.

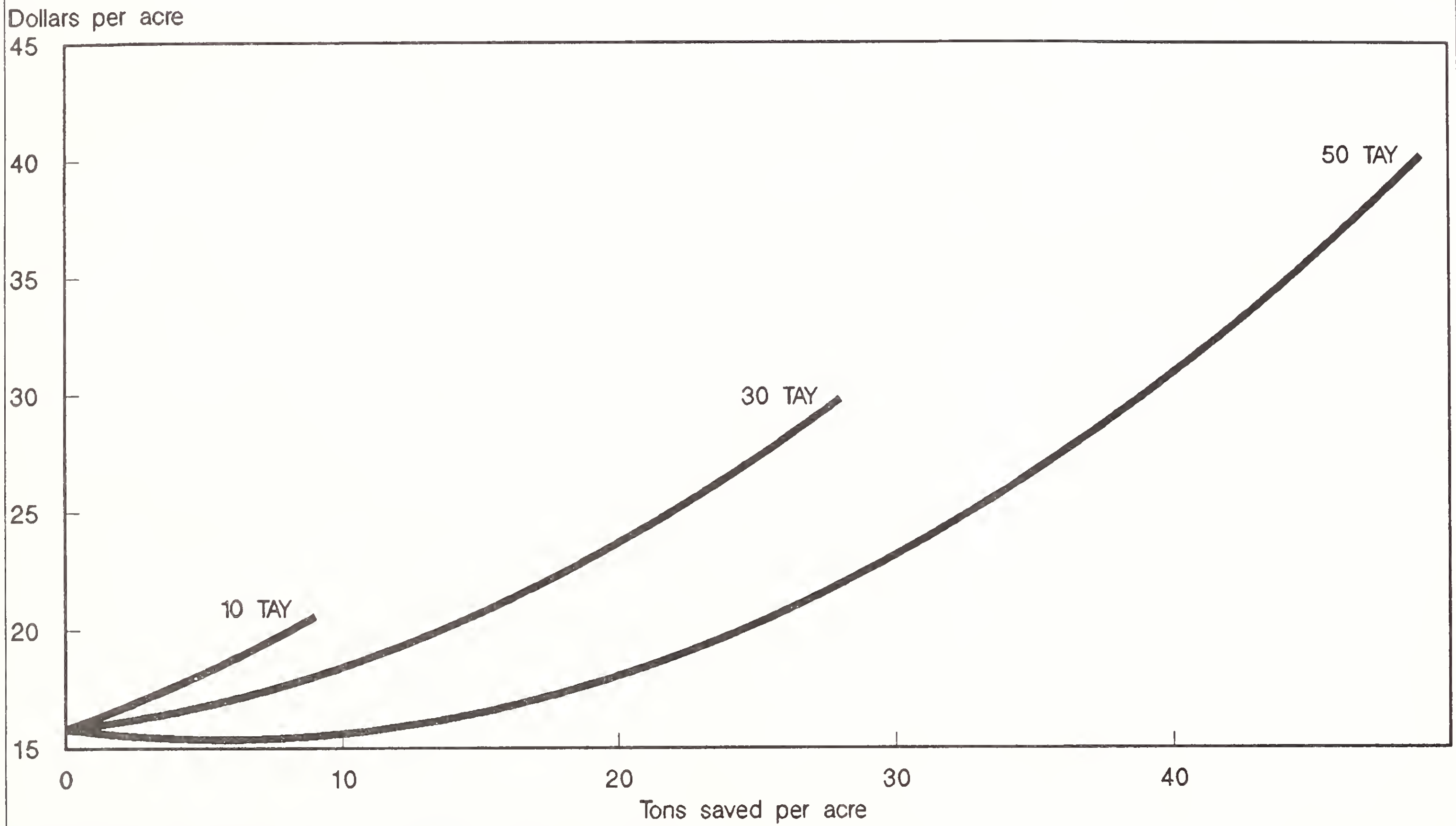
After the simulated enrollment in CRP and the adoption of conservation tillage, about 46 million acres of cropland required further treatment to reduce erosion to T (table 3). The treatment of the 46 million acres

Table 2—Intercept and field size coefficients for the two cost functions

Region	Intercept (Ir)		Field size coefficient (Dr)	
	Model 1[1]	*Model 2*	*Model 1*	*Model 2*
Northeast	10.80*	9.36*	74.04*	73.35*
Appalachia	7.24*	7.81*	25.96*	23.64*
Southeast	2.75	9.31*	101.32*	109.66*
Delta	4.96*	7.49*	84.30*	78.44*
Corn Belt	10.65*	8.73*	154.78*	153.43*
Lake States	2.23	.93	160.78*	158.73*
Northern Plains	6.49*	4.70*	60.44*	59.72*
Southern Plains	2.31**	.48	70.68**	70.09**
Mountain	–1.18	.40	181.49*	170.37*
Pacific	–2.14	6.17	519.66*	465.10*

*=estimates are significantly different (at 0.05 level) from Southern Plains estimates.
**=significantly different from zero.
[1]Model 1 parameters are estimated from all selected CRES records. Model 2 parameters are based on nonconservation tillage records only.

Figure 2
Predicted treatment costs on fields eroding at different rates



30-acre field in the Corn Belt: sheet, rill, and wind erosion treated; cost function 1.

Table 3—Regional and national annual costs of reducing erosion to the soil loss tolerance level (T) on U.S. highly erodible cropland

Region	Total[1]	EI ⩾ 8 eroding above T[1]	Above T after CT and CRP[2]	Total treatment cost to reduce erosion to T and and maintain same rotation	Average cost per acre treated[3]	Cost per ton saved[3]
		Million acres			*Million dollars*	
Northeast	8.6	3.7	3.0	56.4	18.98	3.16
Appalachia	16.8	5.9	3.8	66.7	17.66	1.81
Southeast	14.5	2.5	1.4	23.1	16.57	1.90
Delta	20.4	2.3	1.2	21.3	17.30	1.65
Corn Belt	85.5	19.1	11.7	243.1	20.86	1.90
Lake States	33.4	3.9	1.7	13.5	8.07	1.29
Northern Plains	86.5	13.8	5.9	66.6	11.21	1.33
Southern Plains	41.9	13.8	8.2	109.3	13.36	.53
Mountain	33.7	14.7	7.1	46.7	6.15	.56
Pacific	16.4	3.4	1.6	20.7	12.98	1.05
United States	357.8	83.1	45.6	667.4	14.63	1.16

[1]Source: 1982 National Resources Inventory Subset.
[2]Acres still eroding above T after the simulated adoption of conservation tillage and enrollment in the Conservation Reserve Program.
[3]Includes only those acres treated where conservation practices would need to be installed.

of highly erodible cropland is estimated to cost about $667 million annually, an average of $14.63 per acre. Annual per acre costs vary from $6.15 in the Mountain States to $20.86 in the Corn Belt. The estimated costs per ton saved also vary, from $0.53 in the Southern Plains to $3.16 in the Northeast. The cost per acre and cost per ton estimates are based only on those acres treated and only for the tons saved at some cost. Tons saved as a result of the simulated adoption of conservation tillage or enrollment in the CRP are not included.

The $667 million gross expenditure is a preliminary estimate of the additional expenses required to treat to T all highly erodible U.S. cropland eroding above T, after implementation of a 45-million-acre CRP. Part of the expenditure could come from Federal programs such as the CTA and ACP; the remainder would come from the farmer. The estimate assumes that cost savings associated with the use of conservation tillage are just offset by the investment cost required to replace the current, conventional tillage equipment. Furthermore, this cost estimate probably does not represent the minimum cost of achieving T because the procedure does not allow for changes in land use, such as the establishment of permanent vegetative cover, or for changes in crop rotation, which in some cases may be a less costly means of achieving T.

Tables 4 and 5 show the regional distribution of acreage that would be in compliance with T and 2T at various levels of expenditure. Some 9.1 million acres would require expenditures greater than $20 per acre if compliance to T were the rule, whereas only 5.7 million acres would require expenditures greater than $20 to comply with 2T. In both cases, most land requiring over $20-per-acre expenditures is in the Corn Belt, where the average per-acre treatment costs are highest.

Other Studies

Pavelis (*7*) estimated expenditures on soil conservation at approximately $1 billion in 1983, which included both public and private expenditures on all agricultural land, not just highly erodible cropland. In contrast, our procedure estimates the cost of additional conservation measures needed over and above any measures already in place, and it pertains only to highly erodible cropland. How much of the estimated $1 billion is currently spent on the 83 million acres of highly erodible cropland is unknown. However, according to our estimates the amount would have to increase by $667 million to fully comply with T.

Using the CARD linear programming model, which allows for selected changes in crop rotation and implementation of selected conservation measures, English and Frohberg (*3*) estimated that production costs would increase by $1.1 billion if farmers were constrained to maintain erosion at or below T. This figure is considerably higher than our estimate of $0.7 billion. However, because the study frame was all U.S. cropland eroding above T (about 185 million acres), English and Frohberg's cost estimate per acre was much lower, around $6 per acre eroding above T, compared with our estimate of $15 per acre. This large difference can be explained in part by the CARD model's inclusion of alternative rotations, inclusion of less costly acreage requiring treatment (EI <8 but eroding

Table 4—Acreage distribution of expenditure levels required to achieve compliance to soil loss tolerance level (T)

Region	EI ⩾ 8 eroding above T[1]	No expenditure needed[2]	Under $5/acre	Under $10/acre	Under $20/acre	Acres left
	Million acres					
Northeast	3.7	0.7	0.7	0.7	3.0	0.7
Appalachia	5.9	2.1	2.1	2.1	5.1	.8
Southeast	2.5	1.1	1.1	1.2	2.3	.2
Delta	2.3	1.1	1.1	1.1	2.0	.3
Corn Belt	19.1	7.4	7.4	7.4	14.4	4.7
Lake States	3.9	2.2	2.5	3.5	3.9	[3]
Northern Plains	13.8	7.9	7.9	10.9	13.4	.4
Southern Plains	13.8	5.6	7.9	9.9	12.3	1.5
Mountain	14.7	7.6	11.8	13.4	14.4	.3
Pacific	3.4	1.8	2.0	2.3	3.2	.2
United States	83.1	37.5	44.5	52.5	74.0	9.1

[1]Source: 1982 National Resources Inventory.
[2]Cropland eroding at or below T after simulated costless adoption of conservation tillage and enrollment in Conservation Reserve Program.
[3]Fewer than 50,000 acres.

Table 5—Acreage distribution of expenditure levels required to achieve compliance to twice the soil loss tolerance level (2T)

Region	EI ≥ 8 eroding above 2T[1]	No expenditure needed[2]	Under $5/acre	Under $10/acre	Under $20/acre	Acres left
	Million acres					
Northeast	2.5	0.9	0.9	0.9	2.1	0.4
Appalachia	4.8	2.5	2.5	2.5	3.9	.9
Southeast	2.0	1.0	1.0	1.2	2.0	[3]
Delta	2.0	1.1	1.1	1.2	1.9	.1
Corn Belt	16.2	7.7	7.7	7.7	13.3	2.9
Lake States	2.6	1.6	2.0	2.4	2.6	[3]
Northern Plains	8.8	5.9	5.9	7.3	8.5	.2
Southern Plains	11.5	5.0	6.6	8.3	10.5	1.0
Mountain	10.6	6.6	8.9	10.0	10.5	.1
Pacific	2.8	1.5	1.8	2.1	2.7	.1
United States	63.8	33.8	38.4	43.6	58.0	5.7

[1]Source: 1982 National Resources Inventory subset.
[2]Cropland eroding at or below 2T after simulated costless adoption of conservation tillage and enrollment in Conservation Reserve Program.
[3]Fewer than 50,000 acres.

greater than T), and other exogenous variables (crop prices and production costs) that affect farm income. The CARD model also attributes large cost savings to the adoption of conservation tillage where there are cost reductions, and we do not subtract these cost savings from the cost of the compliance.

Our cost equations predict average treatment costs. They estimate regional average costs by field size and erosion rate treatment. The actual level of expenditures on erosion control will depend on the required level of compliance, the profitability of maintaining eligibility for commodity program benefits, participation in the CRP, and onsite benefits due to the soil savings. McSweeny and Kramer modeled a representative farm in southeastern Virginia and concluded that the farmer would probably choose to comply to retain commodity program benefits (*6*). Batie and Sappington discuss the interdependence between the level of compliance (soil loss restrictions of 5, 10, 15, and 20 TAY) and farmer participation (*1*). They concluded that farmers in a Tennessee county would base decisions on the required level of compliance, the availability of cost-sharing funds (for implementing compliance practices), and their recognition of onsite benefits.

Conclusions

Estimating the installation costs of soil conservation practices is one step in evaluating the potential impacts on agriculture and the environment of conservation compliance. The cost of reducing erosion to T on the Nation's highly erodible cropland was estimated to be as high as $667 million per year, $15 per acre. The actual cost to the farmer would depend on the availability of publicly funded cost sharing and technical assistance and a farmer's choice to maintain eligibility for commodity program benefits. Treatment costs are only one factor affecting decisions about conservation compliance. Benefits are another important factor. A more complete evaluation of the compliance provision and of alternative compliance criteria would include a consideration of benefits.

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The Stochastic Coefficients Approach to Econometric Modeling, Part II: Description and Motivation

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Abstract. *A general stochastic coefficients model developed by Swamy and Tinsley serves as a reference point for discussion in this second of a series of three articles. Other well-known specifications are related to the model. The authors weigh the advantages and disadvantages of stochastic coefficients and suggest procedures to address the identification and estimation problem with weaker and noncontradictory assumptions. They argue that the real aim of inference is prediction and that "imprecise" parameter estimates of a coherent model are acceptable if they forecast well.*

Keywords. *Stochastic coefficients, fixed coefficients, time series analysis, Bayesian inference, identification, coherence, estimation.*

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Although classical logic and probabilistic logic provide different rules of inference, both types of logic are useful in econometrics, as Swamy, Conway, and von zur Muehlen (*27*) and Swamy and von zur Muehlen (*31*) have shown.[1] The purpose of these rules of inference is to indicate what conclusions may be inferred from what premises. If we do not adhere to either type of logic, the conclusions we draw from given premises may be invalid. For example, after estimating a fixed-coefficients model, the econometrician who adjusts the estimate of a constant term or the estimates of some other parameters like the autoregressive coefficient of the error process, while retaining the original estimates of the remaining parameters to obtain good forecasts, may violate one or more of the probability laws. If any probability law is violated in the process of drawing an econometric inference, the resulting inference will be incoherent. There is no logic associated with such an inference.

Our economic inferences may also be invalid if our premises are contradictory. Surely any inference based on a model is valid if the assumptions underlying the model, including those used for estimation and forecasting, do not contradict each other. Extraneous restrictions necessitated by a fixed-coefficients approach need not be free from contradictions, as we have shown in Part I of this article (*26*). (See also Swamy and von zur Muehlen (*31*)). One alternative is to consider models with coefficients that are not fixed and thereby remove the necessity for extraneous restrictions that introduce contradictions. In Part I, we showed that fixed-coefficients models may be inappropriate for other reasons as well. These reasons include aggregation effects, changes in tastes, technology, institutions, and even policy.

Many research papers have dealt with the estimation of a regression model in which some or all of the slopes are both time-dependent and stochastic. Our primary purpose here is to evaluate the estimation methods suggested for these models. To do so, we describe a general model, developed by Swamy and Tinsley (*30*), to serve as a touchstone. We also compare other specifications with the general model to handle the identification and estimation problems with weaker and possibly noncontradictory assumptions.

Introducing a Model with Stochastic Slopes

A regression model whose coefficient vector is time-dependent asserts that a scalar dependent variable y_t is time-generated in accordance with:

$$y_t = x_t'\beta_t \qquad (t=1, 2, ..., T) \qquad (1)$$

where x_t' is a $1\times K$ vector of observations on K independent variables, and β_t is a $K\times 1$ vector of coefficients.

It is assumed that:

$$\beta_t = \Pi z_t + J\xi_t \qquad (t=1, 2, ..., T) \qquad (2)$$

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[1]Italicized numbers in parentheses refer to items in the References at the end of this article.

where Π is a $K \times m$ matrix of fixed coefficients, z_t is an $m \times 1$ vector of observable variables, J is a $K \times n$ matrix of fixed elements, and ξ_t is an $n \times 1$ vector of unobservable variables.[2]

Regarding ξ_t, it is assumed that:

$$\xi_t = \Phi \xi_{t-1} + e_t \tag{3}$$

where Φ is an $n \times n$ matrix, e_t is an $n \times 1$ random vector with $E(e_t | \xi_{t-1}, z_t, x_t) = E(e_t) = 0$ for every t, and $E(e_t e_s' | \xi_{t-1}, z_t, x_t) = \Delta_e$ if $t = s$ and 0 if $t \neq s$.

The first element of each x_t and z_t may be identically equal to 1 for all t, with the coefficient corresponding to these unit elements representing a time-varying intercept and a constant vector, respectively. Since the usual additive disturbance term that appears in conventional econometric models with fixed coefficients cannot be distinguished from a time-dependent stochastic intercept term without the imposition of severe restrictions, both specifications are combined into a single term. That is, the coefficient corresponding to the unit element of x_t represents the sum of the additive disturbance term and a time-varying intercept. Thus, it is not correct to say that the usual disturbance term is omitted in equation 1.

Note that the vectors x_t and z_t may not be completely distinct. All those elements of x_t that are believed to be correlated with β_t can be included in z_t. We will clarify the reasons for defining z_t this way.

Note also that equation 3 is less restrictive than it may seem. The equation represents a first-order autoregressive process only when $J = I_K$ and $n = K$. If J is a $K \times (p+q)K$ matrix having the columns of I_K as its first K columns and zeros elsewhere and if $n = (p+q)K$, then equation 3 represents the following mixed, autoregressive, moving-average process:

$$\varepsilon_t = \sum_{i=1}^{p} \Phi_i \varepsilon_{t-i} + \sum_{j=1}^{q} \Theta_j a_{t-j} + a_t \tag{4}$$

where ε_t, ε_{t-i} 's, a_t and a_{t-j}'s are Kxl vectors; Φ_i's and Θ_j's are $K \times K$ matrices; and $\{a_t\}$ is a sequence of uncorrelated $K \times 1$ random vectors, each with mean vector zero and constant covariance matrix $\sigma^2 \Delta_a$(*30*).

[2]Kmenta (*13*, p. 574) comments that "A troublesome aspect of Swamy's model is the assumption that the 'average' coefficients are constant over time." He is apparently unaware of Swamy and Tinsley's (*30*) equation 2 above, which permits the "average" coefficients to vary over time. However, Kmenta's criticism does apply to the other stochastic coefficients models he surveyed.

The time profile of $\beta = (\beta_1', \beta_2' ..., \beta_T')'$, which is smoother than the profile implied by equations 2 and 3, is obtained if these equations are replaced by the following equation:

$$R\beta = v \tag{5}$$

where $R\beta$ represents the d_j+1 th order difference of the values of the jth coefficient in β and where v is a random variable with mean vector zero and a diagonal covariance matrix. It follows from Shiller (*25*) that equation 5 implies some smoothness restrictions on β.

The First Two Moments of Variables in Equation 1

First, consider equations 1-3. Then, inserting equation 2 into equation 1 gives:

$$y_t = x_t' \Pi z_t + x_t' J \xi_t \tag{6}$$

Equation 3 implies that, given x_t and z_t, the mean of y_t is $x_t' \Pi z_t$. It also implies that:

$$E(\xi) = 0,\ E(\xi_t \xi_t') = \Gamma_0 = \Phi \Gamma_0 \Phi' + \sigma^2 \Delta_e, \\ E(\xi_t \xi_{t-s}') = \Phi^s \Gamma_0 \text{ and } E(\xi_t \xi_{t+s}') = \Gamma_0 \Phi'^s \tag{7}$$

Therefore, defining $u_t = x_t' J \xi_t$ gives:

$$E(u_t) = 0 \text{ and } E(u_t u_{t-s}) = x_t' J \Phi^s \Gamma_0 J' x_{t-s} \tag{8}$$

From equation 8 it follows that the covariance matrix of $u = (u_1, u_2, ..., u_T)'$ is:

$$\Sigma_y = [x_i' J \Phi^{i-j} \Gamma_0 J' x_j \text{ if } i \geqslant j \text{ and } x_i' J \Gamma_0 \Phi'^{j-i} J' x_j \text{ if } i < j] \tag{9}$$

Σ_y is also the covariance matrix of $y = (y_1, y_2, ..., y_T)'$.

Next, if equation 5 is assumed instead of equations 2 and 3, then the first two moments of y and β may be derived as in Kashyap and others (*12*).

Special Cases of Equations 1-3

The following 10 models, which are frequently considered by econometricians, are special cases of equations 1-3.

Box-Jenkins' type model (*1*). In the case where all the elements of Π, Φ_i's, Θ_j's, and Δ_a other than the leading diagonal elements are zero, model 1 reduces to a univariate autoregressive-moving-average (ARMA) model. In turn, this univariate ARMA model reduces to the autoregressive-integrated-moving-average (ARIMA) variant if some of the roots of the

following autoregressive polynomial equation are unity:

$$1-\phi_{111}\zeta-\phi_{211}\zeta^2-, \ldots, -\phi_{p11}\zeta^p = 0 \tag{10}$$

where ϕ_{111}, ϕ_{211}, ..., ϕ_{p11} are the leading diagonal elements of the matrices, Φ_1, Φ_2, ..., Φ_p, respectively, and ζ is a complex number.

A fixed-coefficients model with an ARMA or ARIMA error term. The conventional fixed-coefficients model with an ARMA or ARIMA error term is obtained if all the elements of Φ_i's, Θ_j's, and Δ_a other than the leading diagonal elements are zero. This fixed-coefficients model will not be a reduced-form equation if some of the elements of x_t are endogenous. It also reduces to a model having dummy or deterministic variables as some of its explanatory variables if these dummy or deterministic variables are included in z_t.

A fixed-coefficients model with a heteroscedastic error term. Equations 1-3 are equivalent to a fixed-coefficients model with a heteroscedastic error term if $\Phi_i = 0$ (i=1, 2, ..., p), $\Theta_j = 0$ (j=1, 2, ..., q), and all the elements of Δ_a except one diagonal element corresponding to a nonconstant element of x_t are zero. Such a fixed-coefficients model will not be a reduced-form equation if some of the elements of x_t are endogenous.

A model with time-dependent deterministic slopes. The last set of K–1 equations in equation 4 reduces to a set of deterministic difference equations if all the elements of Δ_a and Θ_j's except the leading diagonal elements are zero. In this case, the slope coefficients of equation 1 are time-dependent deterministic parameters even when all the columns of Π except the first are null.

Autoregressive conditional heteroscedastic (ARCH) models. The ARCH model proposed by Engle (*6*) can be considered as a special case of equations 1–3, obtained by replacing y_t in equation 1 by $y_t^* = (y_t - x_t'\alpha)$ with fixed α, replacing x_t in equation 1 by $(1, y_{t-1}^*, \ldots, y_{t-K+1}^*)$, settng Π in equation 2 equal to a null matrix, zeroing the Φ_i's and Θ_j's in equation 4, and setting Δ_a equal to a diagonal matrix.

An equation embedded in a VAR model. Equation 1 will have the form of an equation embedded in a vector autoregressive (VAR) model if the vector x_t consists of lagged y's and current and lagged values of variables other than y, if all the columns of Π except the first are null, if all the matrices Φ_i's and Θ_j's are null, and if all the elements of Δ_a other than the leading diagonal element are zero.

Hildreth and Houck's model. Equation 1 reduces to Hildreth and Houck's (*10*) model if all the columns of Π except the first are null, if all the matrices Φ_i's and Θ_j's are null, if Δ_a is diagonal, and if all the elements of x_t' are fixed.

Fisk's model. The model consisting of equations 1, 2, and 4 is the same as that of Fisk (*7*) if all the elements of x_t' are fixed, if all the columns of Π other than the first are null, and if all the matrices, Φ_i's and Θ_j's, are null.

A disequilibrium model. Equation 1 is either a demand or a supply function for a market in disequilibrium if two conditions hold. First, if the first element of β_t can be separated from an additive disturbance term so that β_t is independent of the disturbance term. Second, if β_t follows a discrete distribution such that the conditional probability density function (pdf) of y_t, given x_t', is equal to the ratio of two probability values, each of which is less than unity, times the pdf of the normal distribution with mean $x_t'\beta$ and constant variance σ^2. These probability values are time dependent (*18*).

A restricted version of the Kalman model. Equations 1-3 give a version of Kalman's model if an additive error term can be separated from the first element of β_t, if the additive error term is serially uncorrelated and also uncorrelated with β_t in every period, if Π is null, if $J = I_K$, if Φ and Δ_e are known, if the mean and the variance of the additive error term are known, and if the conditional mean and the conditional covariance matrix of β_t, given y_t for t = 1, are known (*5*). In some Kalman filter applications, equations 2 and 4 with the restrictions that $\Pi = 0$, $\Phi_1 = I_K$, $\Phi_i = 0$ (i = 2,..., p), and $\Theta_j = 0$ (j = 1, 2,..., q) are used. In this case the constant mean of β_t is indeterminate and equation 1 cannot be written in the form of equation 6.

The Cooley-Prescott and Rosenberg Models

Cooley and Prescott (*2*) and Rosenberg (*24*) also consider equation 1, but make assumptions that differ from our equations 2, 3, and 5. The maximum likelihood estimators for all the unknown parameters of these models do not exist and there are no other operational methods of estimating these models.

A Priori Restrictions

Several of the models considered in the econometric literature are the restrictive forms of equations 1–3. Building models so as to have each equation satisfy one

or another set of these restrictions requires a priori considerations about the forms of economic laws that are within the purview of coherent economic theories.[3] Any set of contradictory restrictions or restrictions violating the conditions under which empirically interpretable models exist should be rejected outright. The a priori restrictions needed to deduce conventional fixed-coefficients models from equations 1–3 may be contradictory and may violate the conditions under which these models exist, as shown in Part I of our series of articles (*26*); see also (*31*). Restricted models could be justified only if one could find empirically that models so restricted were still coherent (or free from contradictions) and performed better in prediction than models not so restricted.

This is not to say that equations 1–3 (or 1 and 5) should be used without restrictions. The above argument only calls for caution in imposing any restrictions on equations 1–3 (or 1 and 5). If we want to analyze equations 1–3 (or 1 and 5) without imposing any restrictions because we are afraid that any restrictions on these equations might introduce contradictions, then we may have to use arbitrary values for the parameters of the equations. These arbitrary values might lead to unreasonable results or poor forecasts. Coherent zero restrictions on Π, $J\Phi$, and Δ_a may exist. We may find these restrictions by comparing the out-of-sample forecasting performance of different restrictions. We present examples of such comparisons in Part III. Thus, models consisting of equations of the type 1–3 (or 1 and 5) with unknown Π, Φ, and Δ_a (or moments of β implied by equation 5) have advantages as well as disadvantages over conventional fixed-coefficients models.

Advantages of Stochastic Coefficients Models

In stating equations 1–3, we have not violated any probability laws. Indeed, all three assumptions represented by equations 1–3 are consistent with a formal axiomatic foundation of probability theory. Therefore, the procedure for verifying the logical consistency of these equations is relatively straightforward. The additive error term that appears in nearly every conventional fixed-coefficients model can be added to its fixed intercept. Thus, conventional fixed-coefficients models can be viewed as models with random intercept and fixed slopes. The assumption that an intercept is random and slopes are fixed is just as arbitrary as the assumption that all coefficients are random. Because any assumption about the unobservable β_t is necessarily arbitrary, equations 1 and 2 prudently impose a *minimal* set of assumptions that avoid contradictory restrictions. Of course, no one can *prove* that assumptions 1–3 are true, but at least the logical requirement of coherency is satisfied. Use of equations 1 and 5 may involve some contradictions if we are not careful. The necessary precautions we should take to avoid contradictions are explicitly stated in Thurman and others (*33*) and Kashyap and others (*12*).

Conventional approaches yield a set of problems that require some major modifications to capture important higher order nonlinearities and nonstationarities. One offered solution is to find stationarity-inducing transformations (for example, Box-Jenkins) yielding forms that can be subjected to conventional techniques suitable to stationary processes. Because in any given case the appropriateness of such transformations is always uncertain, it would be desirable to find a methodology for which this doubt is not present. One such approach is given by equations 1–3 where it is shown that problems of first- and second-moment nonlinearities and nonstationarities, including those caused by heteroscedasticity, can be dealt with in natural ways that do not require the imposition of unverifiable and possibly contradictory assumptions.

Equations 1–3 will coincide with a stochastic law defined by nature's behavior if and only if x_t and z_t are uncorrelated with e_t, as shown by Pratt and Schlaifer (*22*) for a model that is simpler than equation 1. Assumptions 2 and 3 state that ξ_t is mean independent of x_t and z_t. It follows from Pratt and Schlaifer's argument (*22*) that this mean independence condition is satisfied unless any nonconstant elements x_{it} of x_t and z_{it} of z_t are directly or indirectly affected by any element β_{jt} of β_t or by any nonconstant variable not included in x_t and z_t that either affects or is affected by β_{jt}.

We have shown in Part I (*26*) that an instrumental variables method of estimating an equation with fixed coefficients can introduce contradictions. In contrast, one can handle "simultaneous equations" complications within the framework of equations 1-3 without using any instruments. Suppose that equation 2 is part of a larger model. In this case, regressors may be correlated with the contemporaneous errors. Then, elements of x_t are correlated with those of β_t, which means they also appear in z_t on the right side of equation 2. The vector $J\xi_t$ is that part of β_t not correlated with z_t if equations 1-3 define a stochastic law. Under this condition, we may assume that $J\xi_t$ is mean independent of z_t. Thus, to estimate equations 1-3, we do not need any instruments excluded from equation 1, even when some or all of the elements of x_t are endogenous. The possible correlations between β_t and

[3]Zellner (*34*) has shown that Feigl's definition of causality, namely "predictability according to a law or set of laws," applies to complete econometric models regardless of whether the models satisfy these a priori restrictions or not.

x_t and between an additive error term and x_t are ignored by Pagan (*21*).

Another feature of equations 1-3 is that they are identifiable even when the number of exogenous variables excluded from equation 1 is zero or smaller than the number of endogenous variables included in equation 1 minus one. Even if all the right-hand-side variables in equation 1 are endogenous, they can all be included on the right-hand side of equation 2, and equation 6 is identifiable in this case. This feature is a clear advantage when we do not know the truth of exclusion restrictions and the exogeneity of variables. Equations 1-3 give a coherent method of identifying and estimating coefficients that change over time without the need for instruments, restrictions, or ad hoc adjustments that might introduce contradictions.

Equation 6, obtained by inserting equation 2 into 1, reveals that the representation of a process in 1 and 2 is equivalent to a fixed-coefficients nonlinear model with serially correlated and heteroscedastic errors of a very general form. If regression models with heteroscedastic or serially correlated error terms covered in econometrics textbooks represent economic laws, then so does equation 6. To obtain a textbook-type model, we should impose certain zero restrictions on Φ_i's, Θ_j's, and Δ_a that could contradict each other. Our intent in working with equation 6 is not to ask "woolly" questions and receive "woolly" answers (in Maddala's sense (*17*, p. 403)) or to unnecessarily complicate the analysis, but to avoid introducing contradictory restrictions. It seems that some researchers would rather use a fixed-coefficients model because such a model supposedly answers "nonwoolly" questions than use the coherent set of equations 1-3, even if the former is incoherent. Models with contradictory premises cannot be true. Therefore, we prefer to risk so-called "woolly" answers if the likely alternative is incoherence. In any case, the temptation to think that equations 1-3 lack the explanatory power of a conventional fixed-coefficients model is unwarranted.

Kmenta makes two criticisms of stochastic coefficients models: (1) "the models are not justified by theory" and (2) the "use of varying coefficients models implies that we have given up trying to find the real causes of . . . [coefficient] variation" (*13*, p. 578). Since these criticisms are representative of general comments made by others, we think it is appropriate to respond to Kmenta here.

A widespread practice among econometricians is to add a stochastic error term to a mathematical model somewhat arbitrarily to represent *unidentified* factors and to make the meaningless or false assumption that at least some of the included variables are uncorrelated with those unidentified factors, as rightly pointed out by Pratt and Schlaifer (*22*, p. 11). Kmenta follows this practice and criticizes stochastic coefficients models that depart from it. Just as the mathematical calculus is used by economists to rigorously derive mathematical models of economics, so the probability calculus should be used to rigorously derive stochastic models of economics. The derivation of stochastic coefficients models, unlike the derivation of fixed-coefficients models, does not violate the probability laws, as Swamy and von zur Muehlen show (*31*). Therefore, it is not true that the stochastic coefficients models are not justified by theory. Furthermore, the use of stochastic coefficients models represents an attempt to acknowledge as well as to model explicitly the coefficient variation but not to give up trying to find the real causes of coefficient variation, as suggested by Kmenta. Of course, no one can prove that a model of coefficient variation or the convenient assumption of fixed slopes is true. Any assumption about the purely unobservable coefficients is largely arbitrary. The reason is that the tests of the constancy of regression slopes against a general alternative have low power and hence are not informative. In any case, stochastic coefficients models have the advantage of being able to predict future values of observable variables at least as well as their fixed-coefficients counterparts, as we will show in Part III.

In view of Swamy and von zur Muehlen's (*31*) demonstration that it is impossible to be sure of the true causes of even the observable effects, it may be impossible to follow Kmenta's suggestion that we can find the real causes of coefficient variation. The probability theory teaches us how to be coherent, but it does not tell us how to find the real causes of coefficient variation.

The Kalman model, which separates an additive error term from the first element of β_t, does not have the advantages of equations 1-3 because it cannot take into account the possible correlations between an additive error term and x_t'. Besides, how can any econometrician know the values of Π, Φ_i's, Θ_j's, and Δ_a to implement the Kalman filter formula empirically? Meinhold and Singpurwalla's stereotyped Bayesian interpretations (*20*) of a Kalman filter do not apply to equations 1-3, if in equation 1, an additive error term is correlated with β_t and, hence, cannot be separated from the first element of β_t. Furthermore, the convenient prior distributions employed by Meinhold and Singpurwalla (*20*) and by Doan, Litterman, and Sims (*4*) in their applications of Kalman's filter are arbitrary.

When the derivation of a subjective probability distribution from the Bayesian assumptions of coherent behavior is not possible, then an arbitrary and conven-

ient distribution is used in place of a subjective prior distribution. Using Pratt and Schlaifer's argument (*22*, p. 21), we can show that, if Πz_t is the effect of x_t on y_t and if α is specified incorrectly as the coefficient vector of x_t in the regression of y_t on $(x_t', z_t')'$, a Bayesian analysis that is based on a prior distribution of α alone and that ignores the difference between Πz_t and α will be as inconsistent as the usual methods. Any full Bayesian analysis will be inconsistent unless one keeps in mind the possible reasons for differences between Πz_t and α given in this article when assessing a distribution of $\Pi z_t - \alpha$ or of Πz_t, given α. One should not use arbitrary prior distributions regardless of the accuracy of the out-of-sample forecasts they produce.

To see clearly another advantage of equations 1-3 over fixed-coefficients models, consider the case where x_t itself is not observed but the observations on x_t contain measurement errors. It is known in the econometric literature that, when both the left- and right-side variables in a regression equation are measured with error, the regression equation between the observables is not identified unless the ratios of these error variances are known. No econometrician can ever possess this type of prior information. By contrast, such prior information is not needed to estimate consistently equations 1-3. To see why, suppose that the vector x_t' in equation 1 is not observable and the observations on x_t contain measurement errors. In this case, if we replace x_t' in equation 1 by its observable counterpart, say $x_t^{*\prime}$, then $x_t^{*\prime}$ and its coefficient vector, say β_t^*, will be correlated. If, in equation 2, we replace β_t by β_t^* and if x_t^* is a subvector of z_t, then Πz_t represents that part of β_t^* that is correlated with x_t^* and the remaining subvector of z_t, and $J\xi_t$ represents that part of β_t^* that is uncorrelated with x_t^* and the remaining subvector of z_t. Thus, it is correct to treat the coefficients in the error-in-the-variables models as stochastic and the analysis of such models can proceed even when the ratios of the variances of measurement errors in y_t and x_t are not known, provided x_t^* is a subvector of z_t, and β_t^* is not considered as fixed.

Now we should interpret β_t. In applications considered in nonexperimental sciences such as economics, the model is estimated either from the data that are already available or perhaps from a subjective view of what the data would be like if they were available. In such cases, there is no way to separate what the data say about β_t from "prior" information about β_t. Indeed, β_t cannot be said to exist prior to the formulation of a model, even though there may be much prior information about which data might be observed. In these situations it is reasonable to assume that the interpretation of β_t is defined in terms of the assumed model and may not refer to the physical reality that the model is intended to represent. We owe this view to Lane (*14*). As a result, we prefer to adopt Lane's interpretation 2 in Part I, that the coefficient vector β_t in equation 1 taking values in an abstract set merely indexes that distribution of y_t. As Lane (*14*) observes, any two experiments with the same index set can be mixed.

Disadvantages of Stochastic Coefficients Models

Like the fixed-coefficients models, equations 1-3 may not represent a real physical process. Yet, the assumption that equations 1-3 represent a real physical process is needed for the validity of the argument here. A convenient algebraic expression for this assumption is that the distribution of $y = (y_1, y_2, \ldots, y_T)'$, given x_t' and z_t' for $t=1, 2, \ldots, T$, implied by equations 1-3, is indexed by θ and belongs to the following known class:

$$\mathcal{P} = \{ P_\theta, \ \theta \varepsilon \Theta \} \tag{11}$$

where each of the parameters of equations 2 and 3 is an element of θ and Θ is the parameter space. Here θ is a possible value for some real physical parameter, and the distribution P_{θ_0} belonging to $\mathcal{P}$ is to be regarded as the distribution that actually generated the data when θ_0 was the true value of that parameter.

Mäkeläinen, Schmidt, and Styan have shown that the maximum likelihood estimate of θ exists and is unique if a twice continuously differentiable likelihood function is constant on the boundary of the parameter space Θ and if the Hessian matrix of second partial derivatives of the likelihood function is negative definite at the points where the gradient vector of the function vanishes (*19*). They have also shown that the condition of constancy on the boundary cannot be completely removed when there is more than one unknown parameter. Asymptotic theory ensures, for a sufficiently regular family of distributions, that a consistent sequence of solutions to the likelihood equations will be unique from some sample size onwards. However, it is important to find out, as a partial check on the applicability of asymptotic maximum likelihood theory or, more generally, as a step in inspecting the likelihood function, whether the likelihood equations admit a unique solution and whether such a solution actually maximizes the likelihood. This partial check is particularly important in the case of equations 1-3, where the unknown parameters are abundant and the assumption that equations 1-3 represent a real physical process is questionable. Furthermore, if the solution of the likelihood equations is not unique, the usual regularity conditions do not establish the existence of an efficient estimator of θ (*16*, p. 435).

Applying Mäkeläinen, Schmidt, and Styan's argument (*19*, Section 4.3) to equations 1-3 shows that when Je_t is normal and when Π, $J\Phi$, and $J\Delta_e J'$ are unknown, the likelihood function for equations 1-3 does not necessarily tend to zero as the diagonal elements of $J\Delta_e J'$ tend to 0 or ∞. This result means that the likelihood function is not constant on the boundary of the parameter space and, hence, this boundary is not necessarily the region of "minimal likelihood." Therefore, there is a basis to assume that the likelihood equations do not admit a unique solution for Π, $J\Phi$, and $J\Delta_e J'$ and that any such solution is only a local maximum either *inside* the parameter space or on the *boundary*. The occurrence of several maxima of about the same magnitude would mean that the likelihood-based confidence regions are formed from disjoint regions and summarization of data by means of a maximum likelihood estimate and its asymptotic variance could be quite misleading, as is pointed out in the statistics literature. Furthermore, when the sizes of the unknown parameter matrices, Π, $J\Phi$, and $J\Delta_e J'$, are big, the estimates of these parameter matrices obtained by numerically maximizing the likelihood function may be quite unsatisfactory because of overfitting. These difficulties with the maximum likelihood procedure are not appreciated by Rosenberg (*24*), Cooley and Prescott (*2*), Pagan (*21*), Harvey and Phillips (*8*), and Judge, Griffiths, Hill, Lütkepohl, and Lee (*11*, pp. 809-14), among others. If the maximum likelihood estimate of θ does not exist, then Pagan's conditions (*21*), unlike Swamy and Tinsley's conditions (*30*), for the identification of θ are irrelevant.[4] Pagan also mechanically reproduces Crowder's consistency conditions without verifying them. The nonexistence of maximum likelihood estimates or the nonuniqueness of the solutions of the likelihood equations is not a difficulty that arises exclusively in the context of equations 1-3. Swamy and Mehta (*28, 29*) give instances of disequilibrium and simultaneous equations models where the maximum likelihood estimates of fixed coefficients do not exist.

We do not think that anyone seriously believes that he or she can know exactly the values of Π, $J\Phi$, $J\Delta_e J'$ and the conditional mean and conditional covariance matrix of β_t, given y_t, for $t = 1$ appearing in the Kalman filter. We also doubt that, for a Bayesian analysis of equations 1-3, one can find reasonable prior distributions of the parameters Π, $J\Phi$, and $J\Delta_e J'$ with known hyperparameters. There may be no virtue in using arbitrary prior distributions. Therefore, we should have some data-based estimates of these parameters to compare the consequences of using arbitrary a priori values with those of using data-based estimates. Swamy and Tinsley (*30*) developed a technique that provides data-based estimates of Π, $J\Phi$, and $J\Delta_e J'$.[5]

It follows from the derivation of Swamy and Tinsley (*30*), Swamy and Mehta (*28*, p. 596), and Harville (*9*) that, if equations 1-3 are true, then the predictor of a value of y in an out-of-sample period T+s with the smallest variance within the class of linear unbiased predictors is:

$$\tilde{y}_{T+s} = x'_{T+s}(z'_{T+s} \otimes I_K)\mathrm{vec}[\tilde{\Pi}] + x'_{T+s} J\Phi^s \Sigma'_{\xi T}(I_T \otimes J')D'_x \Sigma_y^{-1} \cdot (y - D_x Z_e \mathrm{vec}[\tilde{\Pi}]) \tag{12}$$

where T is the terminal period of the sample; $\mathrm{vec}[\tilde{\Pi}] = (Z'_e D'_x \Sigma_y^{-1} D_x Z_e)^{-1} Z'_e D'_x \Sigma_y^{-1} y$ is the generalized least squares estimator of vec $[\Pi]$, which is the column stack of Π; Φ is as defined in equation 3, $\Sigma_{\xi T}$ is the matrix made up of the last (p+q)K columns of the covariance matrix of ξ_t, $t=1,2, \ldots, T$, $D_x = \mathrm{diag}\,[x'_1, x'_2, \ldots, x'_T]$, $y = (y_1, y_2, \ldots, y_T)'$; Σ_y is as defined in equation 9, and $Z'_e = [z_1 \otimes I_K, \ldots, z_T \otimes I_K]$.

Clearly, the optimal predictor equation 12 is not operational if the parameter matrices $J\Phi$ and $J\Delta_e J'$ are unknown, as they usually are. Swamy and Tinsley (*30*) develop the following estimating equations:

$$\mathrm{vec}[\hat{\Pi}] = (Z'_e D'_x \hat{\Sigma}_y^{-1} D_x Z_e)^{-1} Z'_e D'_x \hat{\Sigma}_y^{-1} y \tag{13}$$

$$\hat{u} = [I_T - D_x Z_e (Z'_e D'_x \hat{\Sigma}_y^{-1} D_x Z_e)^{-1} Z'_e D'_x \hat{\Sigma}_y^{-1}] y \tag{14}$$

$$\hat{\xi}_t = \hat{\Sigma}'_{\xi t}(I_T \otimes J') D'_x \hat{\Sigma}_y^{-1} \hat{u} \quad (t=1, 2, \ldots, T) \tag{15}$$

$$\begin{bmatrix} x'_2 J\hat{\xi}_2 \\ x'_3 J\hat{\xi}_3 \\ \vdots \\ x'_T J\hat{\xi}_T \end{bmatrix} = \begin{bmatrix} (\hat{\xi}'_1 \otimes x'_2) \\ (\hat{\xi}'_2 \otimes x'_3) \\ \vdots \\ (\hat{\xi}'_{T-1} \otimes x'_T) \end{bmatrix} \mathrm{vec}[J\hat{\Phi}] + \mathrm{error} \tag{16}$$

$$\begin{bmatrix} x'_2 \otimes x'_2 \\ x'_3 \otimes x'_3 \\ \vdots \\ x'_T \otimes x'_T \end{bmatrix} \mathrm{vec}[\hat{\Delta}_a] + \mathrm{error} = \begin{bmatrix} x'_2 J(\hat{\xi}_2 - \hat{\Phi}\hat{\xi}_1)(\hat{\xi}_2 - \hat{\Phi}\hat{\xi}_1)' J' x_2 \\ x'_3 J(\hat{\xi}_3 - \hat{\Phi}\hat{\xi}_2)(\hat{\xi}_3 - \hat{\Phi}\hat{\xi}_2)' J' x_3 \\ \vdots \\ x'_T J(\hat{\xi}_T - \hat{\Phi}\hat{\xi}_{T-1})(\hat{\xi}_T - \hat{\Phi}\hat{\xi}_{T-1})' J' x_T \end{bmatrix} (1/\hat{\sigma}^2) \tag{17}$$

$$\hat{\sigma}^2 = (y - D_x Z_e \,\mathrm{vec}[\hat{\Pi}])' \hat{\Sigma}_y^{-1} (y - D_x Z_e \,\mathrm{vec}[\hat{\Pi}])/T \tag{18}$$

$$\hat{y}_{T+s} = x'_{T+s}(z'_{T+s} \otimes I_K)\mathrm{vec}[\hat{\Pi}] + c x'_{T+s} J\hat{\Phi}^s \hat{\Sigma}'_{\xi T}(I_T \otimes J') \cdot D'_x \hat{\Sigma}_y^{-1}(y - D_x Z_e \mathrm{vec}[\hat{\Pi}]) \tag{19}$$

where $c \,\varepsilon\, [0, 1]$ is a constant.

[4]Since Swamy and Tinsley's conditions (*30*) for the identification of θ are related to an estimation method that always works, their conditions are always relevant.

[5]In the National Bureau of Economic Research-National Science Foundation Seminar on Bayesian Inference in Econometrics held at the University of Michigan, Ann Arbor, MI, on Nov. 3-4, 1978, Haitovsky explicitly questioned whether or not Swamy's work had led the profession in the wrong direction. This article is written partly to let the readers judge whether or not Swamy and his associates' work has misled the profession.

Equations 16 and 17 reduce to the usual estimating equations given in econometrics textbooks if all the elements of Φ and Δ_e other than the leading diagonal elements are zero. To solve equations 13-19, we follow an iterative procedure in which $J\Phi$ and Δ_a are initially arbitrarily chosen, but, through iteration, the dependence of estimators on these arbitrary values is eliminated. However, convergence of this iterative procedure may not be achieved unless the conditions of Szatrowski's theorem 5 (*32*) are satisfied. These conditions may not be satisfied if $\Phi \neq 0$ and if Δ_a is not diagonal. The reason for following any iterative procedure that converges is to find the maximum likelihood or nonlinear least squares estimates. If such estimates do not exist, then no iterative procedure converges to those estimates. We have already pointed out that, in cases where $\Phi \neq 0$ and Δ_a is not diagonal, the sufficient conditions for the existence of the maximum likelihood estimate of θ are not satisfied. Therefore, choosing among the estimates obtained in different iterations of Swamy and Tinsley's procedure (*30*) is a problem. One solution to this problem is to choose estimates that give a (local) minimum value for the root mean square error of forecasts of y_{T+s} for s = 1, 2, . . ., S. This procedure avoids overfitting. We should emphasize that the estimates of $J\Phi$ and Δ_a obtained in any iteration may be quite imprecise. However, it is possible that Π is more precisely estimated than either $J\Phi$ or Δ_a, and so the accuracy of the forecast equation 19 might improve if c is set equal to a value less than 1, since the second term on the right side of equation 19 is more heavily influenced by the estimates of $J\Phi$ and Δ_a than is the first term. Rao (*23*) gives an optimal value of c for a model that is simpler than equation 1, and this value is less than 1.

The results based on equations 13-19 are highly nonrobust in the sense that a small change in an observation can make a substantial difference in the parameter estimates. This result occurs because the number of observations per unknown parameter is quite low, unless $J\Phi$ and Δ_a are severely restricted. For this reason, the values of $p>1$ and $q>0$ in equation 4 are not recommended.

A Faustian Bargain? Trading Dilemmas

Perhaps econometricians generally prefer models with fixed slopes because of the disadvantages of assuming that all coefficients in a regression are varying. But fixed-coefficients models also give rise to difficulties, as is shown in Part I. Here then is a dilemma: The robustness of results given by equations 1-3 is quite low and cannot be increased unless we put a sufficient number of restrictions on the parameters of these equations, in which case the equations may reduce to a fixed-coefficients model. However, once restricted, equations 1-3 may have no advantages over a fixed-coefficients model and may suffer from contradictions.

After all, every econometric procedure is based on some often quite special assumptions about underlying distributions and about the relation between the mathematical parameters of those distributions and the "true state" of the world. That these assumptions may only be subjective and may not be factually true is argued by several Bayesians including de Finetti (*3*) and Lane (*14*, *15*). From a subjective viewpoint, the assumption of fixed coefficients, implying that the distribution of each regression slope is degenerate at a point, is more stringent than de Finetti's notion of prevision and his requirements of coherence (*3*). Statisticians and econometricians in the past have appealed to the two contrary principles of parsimony and profligacy to justify ARIMA models of finite order and VAR models of finite order, respectively. Swamy and von zur Muehlen (*31*) demonstrate that the premises of these models can be contradictory. If the principles of parsimony and profligacy clash with the principle of coherence, the former principles should be rejected in favor of the latter principle. The principle of coherence is preeminent, and equations 1-3 may help us empirically implement that principle. The coherence approach prohibits the use of models with contradictory premises, but does not prohibit the use of imprecise parameter estimates, provided those estimates give successful forecasts of future observable values and plausible explanations of past experience.

The nonrobustness of results given by equations 1-3 is of no concern if these equations do not represent a real physical process. To avoid the problem of justifying the unjustifiable physical interpretation of parameters, we follow Lane (*14*, *15*) and argue that the real aim of inference is usually to generate a prediction about the value of some future observables. This goal is particularly appropriate when the model parameters do not represent "real" physical quantities. In this case, the true values of parameters do not exist, and the precision of parameter estimates is not defined. Parameter estimation may then be viewed as a "half-way house" on the road to predicting some relevant future observation. Stochastic coefficients models are ideally suited to the problem of predicting future variables, as we shall see in the next article in this series of three articles.

Conclusions

We have shown here that it is possible to develop an operational set of estimators for all the parameters appearing in a general stochastic coefficients model, but the precision of those estimators may be quite low. The

only way to improve this precision is to impose a large number of zero restrictions on the parameters of the model. However, a stochastic coefficients model so restricted may reduce to a fixed-coefficients model of the conventional type and may suffer from contradictions. We cannot accept contradictory restrictions. Furthermore, even if certain restrictions do not contradict each other, the increases in the precision of the estimators resulting from these restrictions may be spurious. More important, the low precision of an estimator of a parameter is a real cause for concern if the true value of the parameter exists. We cannot be sure that the true value of a parameter exists unless we are sure that the model in which the parameter appears is true. A model with contradictory premises is false, and the true values of its parameters do not exist.

Since the premises of a fixed-coefficients model can be contradictory, we cannot be happy with the robust results that a fixed-coefficients model may give. Econometric logic permits us to say only that, if a model is coherent (or free from contradictions), then it can be true. We cannot establish the truth of a coherent model. We prefer a stochastic coefficients model to its fixed-coefficients counterpart if we can establish only the coherence of the former but not of the latter. Since the real aim of inference is prediction and not parameter estimation, we should not be overly concerned about the imprecision of parameter estimators given by a coherent stochastic coefficients model. Therefore, any parameter estimates, however imprecise, are acceptable if they give successful forecasts of future observations and provide plausible explanations of past experience.

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Book Reviews

A Pearl of Great, But Not Onerous, Price

Handbook of Econometrics, Volume III. *Zvi Griliches and Michael D. Intriligator (eds.). Amsterdam: Elsevier Science Publishers, 1986, 632 pp. $195.00 (for three-volume set).*

Reviewed by Ralph M. Monaco

With the third volume of the *Handbook of Econometrics,* the series is complete. The three volumes follow the plan of most conventional econometric texts, with the earlier essays laying the groundwork of matrix algebra and statistical theory and the subsequent essays proceeding through hypothesis testing, dynamic specification, and other standard topics. The third volume corresponds to the "special topics" section of most standard texts, with 11 essays on diverse advanced topics. The essays are not aimed at the casual reader, and someone without a strong background in econometric theory will find them difficult. They are designed for "professional use by economists, econometricians, and statisticians and for use in advanced graduate econometrics courses." This statement does not imply that the essays are badly written. The opposite is true. The difficulty reflects instead the increasing specialization and complexity of the field.

Volume III is divided into two parts: "Special Topics in Econometrics" and "Selected Applications and the Uses of Econometrics." Several essays address the same, or similar, issues from slightly different viewpoints.

Four of the essays describe methods for motivating and estimating models with discrete or truncated dependent variables. Dhrymes provides an excellent overview of the problems of ordinary least squares in the context of limited dependent variables. He outlines logit and probit estimation and discusses consistent estimation when the dependent variable is truncated. He considers the problem of sample selectivity, a problem that emerges when a model is specified so that whether a particular variable is observed or not (as opposed to what value it takes) depends on another variable, which may or may not be observed. One example of such a structure is the modeling of employment choices. Whether or not a worker accepts a wage depends on whether that wage is above his "reservation" wage, which itself is not observable.

Heckman and Singer extend the analysis of discrete choices to include models in which the dependent variable observations are obtained in discrete time periods, like quarters or months, whereas the underlying decisionmaking process occurs in continuous time. Heckman's essay on "Labor Econometrics" really should be titled "An Index Function Approach to Labor Econometrics." It shows that recent new approaches in labor econometrics are special cases of an index function model—a model in which discrete or censored random variables are really outcomes of underlying continuous random variables subject to a particular sampling scheme. The essay is a full-blown introduction to the index function framework and ties in nicely with the third section of Dhrymes' essay and Heckman and Singer's essay. Finally, Maddala shows that disequilibrium and self-selection models are special cases of switching models; that is, models in which the observations on the dependent variables are generated by a number of different structural regimes. Maddala extensively discusses the economic meaning behind the disequilibrium specification.

Together, this quartet of essays provides an indepth view of the current state of econometric analysis on discrete or censored dependent variables from complementary perspectives. Be warned though that the essays are quite technical and will probably need to be read with an advanced statistics text at the ready.

The contributions by Lau, Deaton, and Jorgenson are related because they all deal with econometric techniques in the context of the most mathematically well-developed bodies of economic theory: consumer and producer theory. Besides being good summaries of econometric developments in these fields, the three essays provide refresher courses in consumer and producer theory as well. Taylor provides a similar service for rational expectations macroeconomic models. Although his essay runs nearly 60 pages, fully two-thirds is devoted to solution concepts and techniques of rational expectations models, rather than to econometrics. Thus it provides a good source for those who need a concise review or an introductory overview of the rational expectations approach. Anyone interested in econometric methods in these areas would do well to use the essays as a starting point.

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Lau's contribution on functional forms is especially interesting. He attempts to develop a schema for choosing the precise algebraic form an econometric model should take. Most of the examples of how to use this schema, however, are drawn from production and consumer theory, where parametric restrictions implied by theory are well known. In these cases, checking for theoretical consistency and functional-form flexibility are well defined. The schema is harder to use where theory is not so well developed mathematically. The important point, however, is that choosing a specific functional form involves tradeoffs among competing criteria, which implies that some sort of weighting mechanism, or utility function, must be used to discriminate among competing functional forms.

Although Lau does not explicitly put forth the idea, the notion of tradeoffs in selecting econometric specification suggests the possibility that debates about econometric technique may actually be debates about the underlying weights given to the competing criteria. One researcher may, for example, attach greater importance to computational ease and linearity in parameters than another, who may value theoretical consistency or functional form flexibility more highly. Should these analysts reach different conclusions with their respective models, it is unlikely that the difference will be resolved by appeal to econometric technique. Instead, the reasons behind each analyst's respective criteria weights should be examined. This area is nebulous at best, however. Calling attention to the notion that how econometric modeling is done depends on the underlying utility function of the modeler is an important, if unemphasized, facet of Lau's contribution.

The remaining essays in volume III are the most accessible to the general reader and, in a sense, deal with more philosophical problems. Griliches addresses data problems. Are data accurately measured? Are data measuring what modelers think they are measuring? How should a modeler cope with imperfect data? Griliches describes the econometric response to three common data problems: measurement error, missing observations, and missing variables. He makes a plea for using our data sets to explore ". . . what is actually going on . . . without trying to force our puny models on them." Such an attitude presents a stark contrast with other essays in the volume which emphasize the theoretical restrictions implied by "puny models."

Fair reviews methods for evaluating and comparing econometric model forecasts and suggests a method of his own. The method attempts to account for four main areas of forecast uncertainty, including model misspecification. Using this method on equations suggested by the theoretical restrictions of producer or consumer theory would be an interesting exercise. Should the resulting equations prove to be substantially misspecified, one would have to wonder, like Griliches, whether we are asking questions that are too precise for the available data.

Klein provides an excellent discussion of the use of econometric modeling in guiding economic policymaking. He makes, however, the questionable assertion that "small [macroeconomic] models are inherently unable to deal with the demands of economic policy formation." Model size is not the relevant issue. Model specification is. A badly specified large model is probably as bad for policymaking as a badly specified small model and is certainly worse for policymaking than a well-specified small model. Only under the dubious assumption that disaggregated models are always better specified than more compact models can Klein's statement be justified. Despite this problem, his essay really should be read by applied economists who want their results to be useful to policymakers.

Volume III represents an important contribution to the econometrics literature. The essays, though largely intended for an audience already possessing a high degree of econometric sophistication, are lucidly written, and the references following each article provide an excellent bibliography. For those whose specializations do not include econometrics, volume III is best used in conjunction with at least one other, more conventional econometrics textbook. In this case, the textbook could be used as background for a particular problem, with this handbook providing a bridge to the more recent literature. Used in this way, volume III has much to offer almost any economist faced with an applied problem in one of the covered areas.

The papers include: (1) "Economic Data Issues" by Zvi Griliches; (2) "Functional Forms in Econometric Model Building" by Lawrence T. Lau; (3) "Limited Dependent Variables" by Phoebus J. Dhrymes; (4) "Disequilibrium, Self-Selection, and Switching Models" by G.S. Maddala; (5) "Econometric Analysis of Longitudinal Data" by J.J. Heckman and B. Singer; (6) "Demand Analysis" by Angus Deaton; (7) "Econometric Methods for Modeling Producer Behavior" by Dale W. Jorgenson; (8) "Labor Econometrics" by James J. Heckman and Thomas E. Macurdy; (9) "Evaluating the Predictive Accuracy of Models" by Ray C. Fair; (10) "New Econometric Approaches to Stabilization Policy in Stochastic Models of Macroeconomic Fluctuations" by John B. Taylor; (11) "Economic Policy Formation, Theory and Implementation (Applied Econometrics in the Public Sector)" by Lawrence R. Klein.

Managing the Commons: New Directions?

Proceedings of the Conference on Common Property Resource Management. *By National Research Council, Panel on Common Property Resource Management, Board on Science and Technology for International Development, Office of International Affairs. Washington, DC: National Academy Press, 1986, 631 pp., $15.00.*

Reviewed by J. Walter Milon

The proceedings of the Conference on Common Property Management, held in Annapolis, MD, on April 21-26, 1985, represents a unique effort to communicate the discussions and conclusions of a group of distinguished scholars and practitioners in the field of international development planning on the issue of common property resource management. The conference objectives outlined by Bromley and Feeny were to: (1) identify specific causes leading to success or failure in common property management using specific performance indicators, (2) develop a research agenda to clarify the causal relationships determining performance, and (3) recommend specific tasks for international agencies and host countries to better understand and use common property management. To accomplish these objectives, a planning committee solicited papers from academicians and international agency personnel involved in research and administration of common property systems across four continents. Papers were circulated prior to the conference so the authors and other participants could focus on discussion about its objectives.

The proceedings, edited partly to integrate the conference presentations and discussions, consist primarily of case studies on different resource systems by specialists plus a few introductory and summary papers that provide perspective on the outcome of the conference. The introductory papers by Oakerson and Runge describe common property resource management as a typical economic problem, namely, how to determine rates of production and consumption from a natural resource to enhance community welfare. They argue that the critical features distinguishing "common" property from "private" property management are: (1) technical attributes of the resource that inhibit separation of ownership and exclusion of nonowners, and (2) distributional objectives of the community to maintain the social structure or to share the risks of dependence on uncertain natural systems (the assurance problem). Although neither Oakerson nor Runge clearly distinguishes common property from other forms of resource management and control, such as contractual limited entry or administrative regulation, they do provide a logical explanation, based on economic theory, of why communities may adopt communal ownership and control over resource systems.

The 20 case studies in the proceedings encompass a broad range of resource systems: fish and wildlife resources, irrigation and drinking water resources, range and pasture land, cropland, and forest and bushland resources. Each study follows a general outline based on Oakerson's analysis in which the technical attributes of the resource and the organization of resource management are used to explain patterns of social interaction and the effect of management on the resource. Many of the studies provide brief, but detailed, historical perspectives on the community and resource system that help us understand the reasons for continuity or change in the management system.

The summary papers by Bromley and Ostrom proffer some general definitions and conclusions from the case studies. Their major points are that: (1) common property should not be viewed as equivalent to open access management since communal management defines and enforces use rights and, (2) the success of any common property arrangement depends on the delineation and enforcement of institutional rules that represent the interests of the community.

The concluding paper by Peters addresses the three objectives of the conference. Her remarks suggest that the participants were unable to define specific measures of performance so that it is difficult to judge the success or failure of common property management. The research and action agendas developed from the discussion indicate a greater need for understanding the role of common property systems in the overall social structure and a need for more cross-cultural studies identifying common principles of management and evolution.

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The papers include: (1) "The Common Property Challenge" by Daniel W. Bromley; (2) "Conference on Common Property Resource Management: An Introduction" by David H. Feeny; (3) "A Model for the Analysis of Common Property Problems" by Ronald J. Oakerson; (4) "Common Property and Collective Action in Economic Development" by C. Ford Runge; (5) "Marine Inshore Fishery Management in Turkey" by Fikret Berkes; (6) "Sea Tenure in Bahia, Brazil" by John C. Cordell and Margaret A. McKean; (7) "Overfishing and Conflict in a Traditional Fishery: San Miguel Bay, Philippines" by Wilfrido D. Cruz; (8) "A Social Dilemma in a Less Developed Country: The Massacre of the African Elephant in Zaire" by Emizet Kisangani; (9) "Common Property Management of Water in Botswana" by Louise R. Fortmann and Emery M. Roe; (10) "Private Rights and Collective Management of Water in a High Atlas Berber Tribe" by Mohamed Mahdi; (11) "Canal Irrigation in Egypt: Common Property Management" by Robert C. Hunt; (12) "Tank Irrigation in India: An Example of Common Property Resource Management" by K. William Easter and K. Palanisami; (13) "Common Property Resource Management in South Indian Villages" by Robert Wade; (14) "Management of Common Grazing Lands: Tamahdite, Morocco" by Neal E. Artz, Brien E. Norton, and James T. O'Rourke; (15) "Oukaimedene, Morocco: A High Mountain *Agdal*" by Jere L. Gilles, Abdellah Hammoudi, and Mohamed Mahdi; (16) "Socioecology of Stress: Why Do Common Property Resource Management Projects Fail?" by Anil K. Gupta; (17) "Commonfield Agriculture: The Andes and Medieval England Compared" by Bruce Campbell and Ricardo A. Godoy; (18) "Information Problems Involved in Partitioning the Commons for Cultivation in Botswana" by Susan G. Wynne; (19) "Institutional Dynamics: The Evolution and Dissolution of Common Property Resource Management" by James T. Thomson, David H. Feeny, and Ronald J. Oakerson; (20) "Collective Management of Hill Forests in Nepal: The Community Forestry Development Project" by J.E.M. Arnold and J. Gabriel Campbell; (21) "People and Resources in Nepal: Customary Resource Management Systems of the Upper Kali Gandaki" by D.A. Messerschmidt; (22) "The Management and Use of Common Property Resources in Tamil Nadu, India" by Piers M. Blaikie, John C. Harriss, and Adam N. Pain; (23) "Minor Forest Products as Common Property Resources in East Kalimantan, Indonesia" by Timothy C. Jessup and Nancy Lee Peluso; (24) "Management of Traditional Common Lands (*Iriaichi*) in Japan" by Margaret A. McKean; (25) "Closing Comments at the Conference on Common Property Resource Management" by Daniel W. Bromley; (26) "Issues of Definition and Theory: Some Conclusions and Hypotheses" by Elinor Ostrom; and (27) "Concluding Statement" by Pauline E. Peters.

The case studies represent the major contribution of the proceedings. The practitioner in an international development agency will find many well-documented analyses of resource management using common property systems that provide valuable operational insights. These analyses may be useful in specific country studies or as reference materials in evaluating or developing common property systems in other areas. The researcher will benefit from the broad geographic and resource system coverage of the case studies and from the historical perspective of the articles. In particular, the comparative study of commonfield agriculture in England and the Andes by Campbell and Godoy and the study of common land management in Japan by McKean describe the linkages between property ownership, government, and social structure in these societies. These studies illustrate the ways in which institutional rules influence individual behavior, such as how limits on harvesting and cultivating the commons in Japan led to family planning and lowered population growth. These historical perspectives are useful complements to North's work on the role of property institutions in economic development in Anglo-Saxon countries.[1]

Many conference proceedings lack integration among individual papers. The authors of the case studies in this proceedings do focus on the objectives of the conference and the opening and closing commentary papers do provide some perspective on the progress of the conference. However, the reader gains little appreciation for the discussion that was the main focus of the conference. And, there is little explanation of how or why the participants reached the conclusions reported in Peters' closing paper. As a result, this volume leaves many unanswered questions about the role of common property management for resource systems.

Although many of the case studies provide excellent descriptions of particular systems, the proceedings does

[1]D.C. North, *Structure and Change in Economic History* (New York: W.W. Norton, 1981).

not provide a clear discussion on the advantages and disadvantages of common property relative to other property ownership systems. Nor does it provide a rationale for understanding why property rights may change from one form to another. This shortcoming is particularly apparent in some case studies in which common property was replaced by private ownership.

Yet the forces causing the transition were only briefly evaluated. Similarly, although some authors acknowledge related works by other researchers on property rights, organization theory, and collective choice, none provides a clear linkage between research on common property systems and research on resource allocation mechanisms.

Despite these shortcomings, the book should be of interest to specialists in international agriculture and resource development. Most readers will find the individual case studies informative, but they will need to do their own cross-study evaluation to identify consistent patterns and relationships between resource systems and the organization of economic activity. At the very least, readers will better appreciate the complexity of natural resource system management and the value of common property organizations in achieving social objectives.

Public Agricultural Research: Is It Making New Friends?

Public Policy and Agricultural Technology: Adversity Despite Achievement. *By Don F. Hadwiger and William P. Browne (eds.). New York: St. Martin's Press, 1987, 126 pp., $37.50.*

Reviewed by Neill Schaller

Hadwiger and Browne's collection of eight papers on a variety of topics related to technology and public agricultural research policy has its heart in the right place. Many people indeed are interested in, though nowhere near as many as are affected by, the payoff and side effects of technology and, therefore, of public research policy.

The editors tell us that public agricultural research institutions continue to be criticized, but that things may be looking up:

> By providing more abundant and inexpensive food for the world's numerous consumers, by extending this technology into developing nations, and by working toward an environmentally sustainable technology, the public agricultural research system has enhanced its "political legitimacy" . . . . Having gained political legitimacy, research institutions should now seek more support on the national and international level (p. 4).

I wonder if this legitimacy is real. In fact, so does Browne himself in another paper later in the book. Even if it is, moving from there to political support represents another hurdle. Hadwiger and Browne admit that public research institutions "must continue to accept the burden of political self-advocacy, recognizing that major beneficiaries are still not effectively organized as supporters" (p. 4).

Marcus traces the history of agricultural research institutions. His is an interesting review of the USDA-Land Grant college system and the shifts in its philosophy, clientele, and research performance. I find it curious, though, that he scarcely mentions two characteristics which explain many of the opportunities and problems facing the system—its unique partnership of Federal and State research and of research and extension education.

The section on "Thinking about Agricultural and Research Alternatives" turns the reader's attention away from history and the policy setting to current developments in U.S. agriculture. Runge assesses farm financial stress in the eighties. He develops the argument that farmers have gone broke, not because they were too small or could not adapt to changing technology, but because their debts were too high. Recognizing that younger, better educated, and technologically advanced farmers have had the highest debt-asset ratios, he fears an erosion of the competitive advantage due to the high quality of human capital that those farmers have brought to American agriculture. Frankly, I am not sure why Runge's paper was included in the book. It is about the structure of agriculture, not research policy. It seems unconnected to the book's primary focus. Runge introduces the point that technology produced by research is not necessarily the cause of financial stress. But he might have contributed more to the book by looking at the effects of farmers' financial problems on their support of agricultural research and on the support from other publics.

Youngberg traces the evolution of what is now widely referred to as "alternative agriculture," an umbrella term for approaches known as sustainable, regenerative, organic, and low-input agriculture. He discusses reasons for growing interest among farmers and the nonfarm public in alternative agriculture. These approaches show promise of being environmentally and economically more sustainable than the capital-intensive, monocultural cropping systems and other highly specialized systems characterizing conventional agriculture. Youngberg exposes the myth that alternative agriculture is a return to low-yield, labor-intensive farming. He also comments on biotechnology, which he believes can be good or bad news for the objectives of alternative agriculture. For example, biotechnology will support those objectives when it is used to develop bacterial pesticides. It works at cross purposes with alternative agriculture when it is used to produce more herbicide-tolerant crop varieties.

In the section on "Current Political Issues and Conflict," the book returns to research policy and political support. Gajbhiye and Hadwiger make the point that

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agricultural research is needed to fight malnutrition. They discuss the performance of national and international research institutions. They suggest a strategy for gaining research support that differs from what Hadwiger and Browne had told us earlier. The editors maintain that the major beneficiaries of agricultural research are not organized and, therefore, that immediate users and researchers themselves must be its principal supporters. Gajbhiye and Hadwiger suggest that "agricultural research institutions should also tout their capabilities to the large constituency of consumer interests" (p. 79).

Browne delves deeply into the questions: who really makes agricultural research policy, and how? His paper is an excellent summary of a study he did on criticisms of agricultural research voiced by different interest groups. Browne makes a convincing case that the agricultural research policy arena is more crowded and noisy than ever before, which could have a numbing effect on research policy directions. Or, too many critical voices could impair both the credibility of agricultural researchers and the ability of their political friends to generate significant support. Browne warns that "as budgetary deficit and funding concerns become intensive, policymakers might well apply the largest and most burdensome cuts to what they see as controversial programs" (p. 88). His advice to researchers and research institutions is to understand the reasons for public criticism of agricultural research, to answer the critics, and to accept chronic uncertainty as to what effect, if any, the criticism and the answers may have on research policy.

Madden challenges researchers and research institutions not only to respond to their critics but "to develop our sciences to the point where we can anticipate and prevent detrimental impacts and thereby achieve a much greater benefit for society" (p. 103). He makes a plea for "a commitment to be scientifically excellent, socially relevant, and ecologically responsible" (p. 107).

Buttel and Kenney take the reader back to biotechnology. They address questions such as: Will biotechnology help the developing countries or cause distortions of the kind that accompanied the Green Revolution? Will it be developed and used to protect environmental quality or simply to increase production? Can developing countries afford it? Like Youngberg, Buttel and Kenney cite potential good and bad news from biotechnology. They see it either as leading to higher standards of living and quality of life in the Third World or as "deepening dependence and distorted development" (p. 119).

I would be tempted to stop here if I believed that the book's intended audience includes only colleagues of the authors and other members of the agricultural research communty. Such an audience should find the eight papers interesting and sometimes insightful. But, if the intended audience includes other participants in the research policymaking process and if the object is to help them increase their knowledge and understanding of research policy issues, options, and consequences, I must give the book low marks. It has no plot. (The title itself, lacking verb-like words, hints of this problem). The papers appear to be a random sampling of information and ideas that are connected loosely, if at all. They tune into different dimensions of research policy from different directions, without much explanation. Some seem to have been written for other purposes (especially Runge's). In fact, one wonders if the outline and the preface were written, and the title selected, to fit the assembled papers.

The editors fail to give readers of all kinds an adequate roadmap to guide their journey through the papers and to keep them out of trouble. Nowhere, for example, even in the preface, is there any discussion of what the editors or authors really mean by things like technology, or even agricultural research. Nor does one find a summary of the major conclusions and puzzlements derived from the papers or of the knowledge gaps they leave behind. In short, the book adds up to no more, and perhaps less, than the sum of its parts.

The book has four parts, "Agricultural Research in a Policy Setting," "Thinking About Agricultural and Research Alternatives," "Current Political Issues and Conflict," and "The Prospects for Agenda Change." The papers include: (1) "Introduction" by Don F. Hadwiger and William P. Browne; (2) "Constituents and Constituencies: An Overview of the History of Public Agricultural Research Institutions in America" by Alan I. Marcus; (3) "Inefficiency and Structural Adjustment in American Agriculture: Who Will Quit and Why?" by Carlisle Ford Runge; (4) "Moving from Yesterday's Agricultural Technology: Alternative Farming Systems in Perspective" by I. Garth Youngberg; (5) "Political Support for National and International Public Research" by Hemchandra Gajbhiye and Don F. Hadwiger; (6) "An Emerging Opposition? Agricultural Interests and Federal Research Policy" by William P. Browne; (7) "Toward A New Covenant for Agricultural Academe" by J. Patrick Madden; and (8) "Biotechnology and International Development: Prospects for Overcoming Dependence in the Information Age" by Frederick H. Buttel and Martin Kenney.

International Agricultural Interdependence A Patchwork Quilt

World Food Policies: Toward Agricultural Interdependence. *By William P. Browne and Don F. Hadwiger (eds.). Boulder, CO: Lynn Rienner Publishers, 1986, 220 pp., $26.50.*

Reviewed by Richard M. Kennedy

The common thread running through this collection of 14 short essays is broad—the interdependence of agricultural policies among nations, or "national food policy as the setting for international food dependency." The project was financed primarily by Resources for the Future, with support from the Farm Foundation and the Policy Studies Organization.

Most of the essays were written in 1984. Their perspective is generally national or regional, and their scope ranges from very broad to quite narrow, with no apparent attempt to deal with common themes. Browne provides an overview, discussing the world agricultural trade environment as it affects U.S. agriculture and forces adjustments in the policies that regulate and support it. Browne includes a catalog of issues arising in world agriculture, and his commentary foreshadows their treatment in the essays that follow. None of the essays provides an integrated international perspective on the character of the future interdependent agricultural system "toward" which the book's title suggests that the world may be moving.

The editors regard their book "primarily as a way in which scholars of public policy—in this case, political scientists—can offer their insights on this subject to an interested audience that includes those who make food policy" (p. ix). However, the two essays that deal with the relationship of U.S. agriculture to the world food system more strongly reflect their authors' training as economists. Both have extensive experience in the policy arena that informs their insights into how economic conditions and relationships present U.S. policymakers with choices at the national level, but neither says much about how political forces shape those choices.

Shuh, for example, persuasively advances the standard economic argument of why a freer world trading environment would permit the United States optimally to exploit international agricultural interdependence through increased agricultural exports. He also touches on the potential benefits to the United States from a lowering of its agricultural import barriers and from a global freeing up of the movement of labor and capital. Shuh acknowledges the obligation of politicians and policymakers to balance the gains and losses of those affected by policy changes for the sake of the common good. However, he does not examine these conflicts and tradeoffs. Mayer provides a capsule analysis of how the growth in importance of U.S. agricultural exports is shaping a variety of issues central to U.S. agricultural trade policy. His treatment of political

The essays include: (1) "Issues of World Food and Trade: Perspectives and Projections" by William P. Browne; (2) "Farm Exports and the Farm Economy: Economic and Political Interdependence" by Leo V. Mayer; (3) "Maximizing U.S. Benefits from Agricultural Interdependence" by G. Edward Shuh; (4) "The Common Agricultural Policy and World Food Trade" by Nicholas Butler and "CAP Update" by Fred H. Sanderson; (5) "Australia and New Zealand: The Role of Agriculture in a Closer Economic Relationship" by Hyam Gold and Thakar Ramesh; (6) "Soviet Agricultural Policy in the 1980's" by Anton F. Malish; (7) "Self-Sufficiency in Japanese Agriculture: Telescoping and Reconciling the Food Security-Efficiency Dilemma" by David N. Balaam; (8) "Food Security and Agricultural Development Policies in the Middle East" by Marvin G. Weinbaum; (9) "Self-Sufficiency, Delinkage, and Food Production: Limits on Agricultural Development in Africa" by Louis A. Picard; (10) "The Policy Consequences of the Green Revolution: The Latin American Case" by Michael K. Roberts, C. Michael Schwartz, Michael S. Stohl, and Harry R. Tang; (11) "U.S.-Mexican Agricultural Relations: The Upper Limits of Linkage Formation" by Gustavo del Castillo and Rosario Barajas de Vega; (12) "The Role of World Food Organizations" by Ross B. Talbot; (13) "The Social, Developmental, and Political Impacts of Food Aid" by James N. Schubert; and (14) "Public Policy and Interdependence" by Don F. Hadwiger.

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factors consists primarily of evidence that bad times in U.S. agriculture, caused in part by falling exports, have been detrimental to congressional job security. Missing in their treatment is any serious discussion of the political role of U.S. institutions or interest groups in promoting, retarding, or shaping agricultural interdependence.

On the other hand, Butler deals with both the economics and the politics of the European Economic Community's (EEC) evolution from a major net importer of agricultural commodities to a leading exporter. He describes how the institutional structure of its Common Agricultural Policy (CAP) encourages a member country to agree to paying of higher prices to another member's producers of a particular leading commodity in exchange for similar concessions to its own producers. Butler believes that the decisionmaking process favors producers and leaves consumers with no effective voice. By showing how other economic interests of France, Germany, and the United Kingdom are paramount, Butler downplays the possibility that the CAP will collapse because of its strain on the EEC budget. He also warns that the admission of Spain and Portugal to the EEC sets the stage for further trade disruptions. Sanderson updates the discussion of the CAP with a description of CAP reforms. He suggests that budgetary strains have encouraged the adoption of measures, especially supply management techniques, that shift costs to consumers and avoid the need to cut producer price supports.

Balaam argues that the Japanese are gradually discarding their old belief that a secure food supply is synonymous with the achievement of domestic food self-sufficiency. Rising incomes have stimulated the demand for imported foods outside the traditional diet, which has helped make the Japanese increasingly less fearful of vulnerability from a heavy dependence on food imports. As a result, the Japanese Government has become less willing to accept economic inefficiencies in domestic production. This shift in perspective on economic policy reflects an erosion of the ruling Liberal Democratic Party's political base in the agricultural sector because of economic and demographic trends. Other sectors have gained more influence, and differences of interest between them and the agricultural sector are becoming blurred.

Balaam believes that the limited Japanese acquiescence to U.S. pressure to liberalized trade actually reflects purposeful choices by the Japanese. "Their strategy is to rationalize agriculture and promote self-sufficiency by withdrawing protection from some inefficient producers and opening them up to competition" (p. 102). Many observers of the recurrent and prolonged U.S. attempts to gain increased access to Japanese markets will question Japan's commitment to that strategy and will discount Japanese arguments about the need to move slowly so as to reconcile opposing domestic interests.

Gold and Thakur examine the role of agriculture in the attempt by Australia and New Zealand to establish a closer mutual trading relationship. That new relationship seems likely to have little effect on the agricultural trade of countries outside the region, especially when compared with potential changes in industrial trade. The main value of the essay was its treatment of the lengthy process by which the two governments worked not only to reconcile conflicting economic interests, but also to build a consensus both within and between their countries in support of a more liberal trading system. This attention to the political process may be instructive to anyone inclined to believe that the success of the current multilateral trade negotiations depends above all else on achieving a technical balance of the welfare gains and losses produced by opposing national trade proposals.

The term "interdependence" pervades the essays dealing with developed countries and largely reflects the attitude that interdependence is potentially beneficial or is an inevitable phenomenon to which nations must adjust. But, in the essays that focus on centrally planned or less developed countries (LDC's), the term is replaced by "dependence" with its more threatening connotation. For example, Malish focuses primarily on Soviet long-term domestic agricultural policy and its aim of reducing Soviet reliance on agricultural imports. He concludes that Soviet efforts to increase agricultural self-sufficiency imply an offsetting increased dependency on the importation of agricultural technology.

Del Castillo and Barajas de Vega explore the linkages between U.S. and Mexican agriculture and find that policy decisions made in either country present policymakers in the other with uncomfortable choices. The Mexican choices are particularly difficult. A key issue is whether to give priority to production of staples for domestic consumption or of higher value agricultural products, such as high quality fruits and vegetables, for export to the United States. The authors argue that emphasis on staples favors both the traditional organizations of the peasantry and the improvement of its low-income status. Emphasis on exports favors modern commercial farm organization that is outside the peasants' control and potentially disruptive to their way of life and economic welfare.

In the process of attempting to resolve opposing arguments about the success of the "Green Revolution" in Latin America, Roberts, Schwartz, Stohl, and Targ

emphasize the undesirable results of dependence for the LDC's. I was uncomfortable about how this team of political scientists and sociologists applied correlation analysis to highly aggregated economic variables with little reference to economic theory.

Wienbaum discusses how the dependence of Middle Eastern countries on foreign food and financial aid can produce unfavorable political reactions to U.S. policy that may outweigh the benefits of increased exports to the region stimulated by the aid. The dependence on food imports, often in the form of food aid, encourages a continuation of food subsidies to urban consumers that depress producer incentives. Efforts to reduce such subsidies, often a condition of assistance from development agencies, may create political unrest that threatens a regime's very existence. Wienbaum concludes that support for greater food self-sufficiency in the region may be in the longer term interest of the United States.

Picard brings the concerns about dependency into coherent focus in an essay that highlights the views of "dependency theorists" who believe that the "terms of trade, choices about what to produce, and patterns of investment are to a large extent not determined by the LDC's" (p. 122). Such decisions are said to be determined by political and economic forces that both "strengthen industrial country dominance over LDC's" and the "dependent upper middle classes," and "keep LDC's in poverty but structurally linked to the needs of the industrialized world" (p. 122).

Picard believes the LDC's face a fundamental dilemma. They would prefer to reject agricultural development strategies based on market incentives and integration with outside economic systems. They view these strategies as providing material incentives only to the few and as forcing LDC's to compete at a disadvantage with the more advanced commercial agricultural sectors of the developed countries. However, according to Picard, direct government administration of development through a strategy of increased self-sufficiency is probably doomed to failure. The reasons are massive administrative, institutional, and political constraints and the failure of the planned economy to demonstrate that ideology or "rhetorical incentives" are successful alternatives to those of a free market in stimulating increased output. Picard's somber assessment is derived from his consideration of African agricultural development, but he believes it is relevant to many LDC's.

Talbot discusses the role of the United Nations Food and Agriculture Organization (FAO), the World Food Council, the World Food Program, and the International Fund for Agricultural Development in relation to U.S. policy. These are the international fora where the LDC's most often confront the developed countries with their concerns about agricultural interdependence. Talbot describes organizations in which the industrialized nations, the developing countries, and the organizations' secretariats engage in coalition politics to achieve their often conflicting objectives. He characterizes the U.S. attitude toward these organizations as "a form of reluctant standpatism" leading to a policy whose primary aim is to defend the status quo. A major reason for waning U.S. enthusiasm has been the dilution of U.S. influence in situations where developing countries have the votes, but industrialized countries supply most of the money for policy innovations. Talbot's perspective helps illuminate recent controversies over U.S. cuts in its contributions to FAO and efforts to force reforms that give developed country donors more say in FAO programs.

Following Farm Practices from Field to Market

Weed Control Economics. By B.A. Auld, K.M. Menz, and C.A. Tisdell. London: Academic Press, Inc., 1987, 177 pp., $39.50.

Reviewed by Katherine Reichelderfer

It's unfortunate that the title of this book will appeal to only a relatively small group of agricultural researchers involved in weed control problems. Too bad, for a broader audience could also benefit from the book's systematic, hierarchical approach to examining a specific farm management issue.

Let's look at the book first from the perspective of its smaller audience. The authors' stated intent is to provide agricultural scientists, decisionmakers, farmers, and policy officials with "a greater appreciation of the economic impact of weeds and the economic assessment of weed control strategies" (p. v). Their book is intended as a guide for anyone who wants to evaluate weed control options. Economists will find it useful, noneconomists, less so. The authors comprehensively review such agronomic phenomena as weed taxonomy, life cycles, seed dispersal, and control methods in a clear, comprehensible fashion for economists to grasp. They also outline basic economic concepts and procedures for the benefit of noneconomists who, with careful reading, could be guided to conduct their own credible economic assessment of weed control options. But, because of the rather liberal use of economic jargon, economists will probably be better informed about the agronomic features of weeds than will agronomists on the subtleties of economic analysis.

Frequent reference to a vast and comprehensive bibliography enhances the book's value. Coverage of the topic is complete. Weeds' effects on, and control in, both crop and livestock systems are thoroughly reviewed. The authors draw on others' work and develop their own empirical examples so that all the major aspects of weed economic assessment are clearly illustrated.

They have unquestionably met their own objective. Nobody who must evaluate or judge another's evaluation of an agricultural weed control option should be without this book.

But a more striking aspect of the book is that it has potential to work on an entirely different level for readers with no particular interest in weed control. The authors have organized the economic exploration of weeds in a methodical manner, tracing the implications of weed management from the smallest, simplest level—a field—to the most complex and all-encompassing level—society at large. The book could easily be used as a blueprint for the systematic evaluation of any farm management practice.

The authors first review weed control economics at the field level, under static and deterministic conditions. They are careful to note the oversimplicity of the concept of economic thresholds for weed control action and simple analytical approaches such as budgeting. Then they introduce dynamic and stochastic elements of farm management, fortifying the basic case and introducing long-term concerns and uncertainty. The chapter on "Weeds in a Farm System" reiterates the fact that the field-level case can be regarded only as a partial analysis, and it proceeds to view weeds in the context of farm-level objectives and constraints. Interactions among components of farming systems are well illustrated, both conceptually and in a detailed empirical example. The authors' advice on using a systems approach is well founded. Next, they support the need for a regional perspective on weed control. Externality issues and noxious weed legislation are reviewed as they relate to the potential for regional spread of weed problems. Finally, commodity price and other market effects, as well as income redistribution possibilities from widespread weed control efforts, are covered from the societal perspective. Standard welfare economics are applied to show who gains and who loses, and by how much, as a result of widespread adoption of effective weed control. Other broad issues, such as the returns to weed control research and development and pesticide regulation, are also reviewed in the societal context.

It is rare to find a single source that so thoroughly and systematically follows the economic implications of a farm practice from field to farm, farm to region, and region to market. Weed control provides a particularly

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good example for such treatment because it incorporates income risk, dynamics, intrasectoral externalities, and, because of herbicide use, broad social issues. Because the book covers an area in which market failure is common, it can be used as a primer for thorough analysis of other complex classes of farm practices. Examples of current interest might include the evauation of agricultural biotechnology or an examination of the potential for "low-input" or "alternative" agricultural systems. I highly recommend the book to students and economists who might benefit from a clear case study on how to evaluate the effects of farm practices from their site of implementation through their implications for society.

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